BBRR

Environment Canada
Environnement Canada

Canada - Ontario Agreement on Great Lakes Water Quality

Ministry of the Environment
Ontario

Phosphorus Reduction from Continuous Overflow Lagoons by Addition of Coagulants to Influent Sewage

Research Report No. 65

Research Report No. 65 Phosphorus Reduction from Continuous Ov

STANDARDS DEVELOPMENT BRANCH OMOE
36936000006969

esearch Program for the Abatement of Municipal Pollution
under Provisions of the Canada-Ontario Agreement
on Great Lakes Water Quality

TD
758.5
.P56
G73
1977
MOE

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Fisheries and Environment Canada, and the Ontario Ministry of Environment, and contracts with municipalities, research institutions and industrial organizations.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Fisheries and Environment Canada
P.O. Box 5050
Burlington, Ontario L7R 4A6

Ontario Ministry of Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

TD
758.5
.P56
G73
1977

Phosphorus reduction from
continuous overflow lagoons by
addition of coagulants to influent
sewage. Graham, H. J.

78904

BBRR

PHOSPHORUS REDUCTION FROM CONTINUOUS OVERFLOW LAGOONS BY ADDITION OF COAGULANTS TO INFLUENT SEWAGE

by

H.J. Graham and R.B. Hunsinger
Ontario Ministry of the Environment

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

Project No. 71-1-16
71-1-17
72-1-25

This document may be obtained from -

Training and Technology Transfer
Division (Water)
Environmental Protection Service
Fisheries and Environment Canada
Ottawa, Ontario
K1A 1C8

Ontario Ministry of the Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

© Minister of Supply and Services Canada 1977
Cat. No. En43-11/65

ISBN 0-662-01178-3

ABSTRACT

To reduce the effluent total phosphorus concentration below 1 mg/l from continuous discharge lagoons, ferric chloride, alum and lime were added continuously and singularly to the influent raw sewage at three waste stabilization ponds. During a two-year observation period, phosphorus and other parameters were monitored to assess the effect of each prime coagulant.

A batch treatment with ferric chloride at one location quickly reduced the effluent phosphorus concentration below 1 mg/l, and the continuous addition of more ferric chloride to the raw sewage maintained the low phosphorus concentration during the entire program. The optimum dosage was found to be 20 mg/l as Fe^{+3}. The continuous alum addition also reduced effluent total phosphorus concentration below 1 mg/l, and the dosage necessary was 225 mg/l alum. With both ferric chloride and alum there was no evidence of resolubilization of the precipitated phosphorus even under anaerobic conditions. With the lime, effluent total phosphorus concentration approached 1 mg/l, but was seldom below that value even with a dosage of 400 mg/l lime. The effluent phosphorus concentration was higher than in the "treated" raw sewage, indicating that resolubilization did occur in the lagoon. As expected the lagoon pH was significantly increased. At all locations there was no appreciable change in any other effluent parameters. The sludge build-up during the experiments was monitored and did not appear to be excessive.

Liquid ferric chloride and alum were readily used in this form of treatment. The hydrated lime as used here was labour intensive and caused numerous problems such as scaling and pump failure.

RÉSUMÉ

On a traité de façon continue mais indépendante les eaux brutes de trois étangs de stabilisation à débordement continu avec du chlorure ferrique, de l'alun et de la chaux afin d'en réduire la teneur en phosphore à moins de 1 mg/l. On a surveillé cette dernière, pendant deux ans, afin d'évaluer les effets de chacun des agents coagulants principaux.

Dans un bassin, l'addition de chlorure ferrique a rapidement ramené la teneur en phosphore de l'effluent à moins de 1 mg/l et son addition continue a permis de maintenir cette faible teneur durant toute l'expérience. On a évalué la dose optimale d'ions Fe^{+3} à 20 mg/l. L'addition continuelle d'alun a donné le même résultat, mais nécessité une dose de 225 mg/l. Le traitement avec ces deux substances ne semble pas suivi d'une remise en solution du phosphore précipité et ce, même en conditions anaérobies. Même à doses de 400 mg/l, la teneur en phosphore de l'étang traité à la chaux ne s'est qu'approchée de 1 mg/l et rarement abaissée sous cette limite. La teneur en phosphore de l'effluent, dépassant celle des eaux brutes traitées, indique une remise en solution dans l'étang. Tel que prévu, le pH des etangs a augmenté de façon significative. Les autres paramètres des effluents n'ont changé nulle part, et l'accumulation des boues, controlée pendant l'expérience, ne nous a pas semblé excessive.

Pour ce genre de traitement, on a pu utiliser tels quels le chlorure ferrique liquide et l'alun. Par contre, l'utilisation de chaux hydratée s'est révélée consumante et a causé de nombreux problémes tels l'entartrage et le bris des pompes.

TABLE OF CONTENTS

		Page
ABSTRACT		i
TABLE OF CONTENTS		iii
	List of Figures	v
	List of Tables	viii
CONCLUSIONS		ix
1.	INTRODUCTION	1
2.	FERRIC CHLORIDE - SUTTON	2
2.1	Methods	2
2.1.1	Site description and ferric chloride addition	2
2.1.2	Jar tests and dosage	4
2.1.3	Sediment build-up	6
2.2	Results and Discussion	6
2.3	Mechanical Problems	12
3.	ALUM - SHELBURNE	13
3.1	Methods	13
3.1.1	Site description and chemical addition	13
3.1.2	Dosage	13
3.2	Results and Discussion	15
3.3	Mechanical Problems	27
4.	LIME - WATERFORD	28
4.1	Methods	28
4.1.1	Site description and chemical addition	28
4.1.2	Jar tests and dosage	30
4.2	Results and Discussion	32
4.3	Mechanical Problems	45
5.	DESIGN CONSIDERATIONS	47
5.1	Alum and Ferric Chloride	47
5.2	Lime	48
REFERENCES		49
ACKNOWLEDGEMENTS		50

TABLE OF CONTENTS (CONT'D)

Page

APPENDIX A 53

APPENDIX B 63

APPENDIX C 71

LIST OF FIGURES

Figure		Page
1	Ferric Chloride Feed System at Sutton	3
2	Sutton - Ferric Chloride Jar Test Results	5
3	Sutton - Ferric Chloride - Effluent Total Phosphorus over the Duration of the Project	7
4	Sutton - Ferric Chloride - Effluent Soluble Phosphorus over the Duration of the Project	8
5	Sutton - Ferric Chloride - Final Effluent BOD over the Duration of the Project	10
6	Sutton - Ferric Chloride - Final Effluent Suspended Solids over the Duration of the Project.	11
7	Alum Feed System at Shelburne	14
8	Shelburne - Alum - East Cell Final Effluent Total Phosphorus over the Duration of the Project	16
9	Shelburne - Alum - West Cell Final Effluent Total Phosphorus over the Duration of the Project	17
10	Shelburne - Alum - East Cell Final Effluent Soluble Phosphorus over the Duration of the Project	19
11	Shelburne - Alum - West Cell Final Effluent Soluble Phosphorus over the Duration of the Project	20
12	Shelburne - Alum - East Cell Final Effluent BOD over the Duration of the Project	22
13	Shelburne - Alum - West Cell Final Effluent BOD over the Duration of the Project	23
14	Shelburne - Alum - East Cell Final Effluent Suspended Solids over the Duration of the Project	24
15	Shelburne - Alum - West Cell Final Effluent Suspended Solids over the Duration of the Project	25
16	Lime Feed System at Waterford	29
17	Waterford - Lime - Jar Test Results	31
18	Waterford - Lime - Raw Sewage Total Phosphorus over the Duration of the Project	33

LIST OF FIGURES (CONT'D)

Figure		Page
19	Waterford - Lime - Total Phosphorus Concentration in the "Treated" Sewage over the Duration of the Project	34
20	Waterford - Lime - Effluent Total Phosphorus over the Duration of the Project	35
21	Waterford - Lime - Effluent Soluble Phosphorus over the Duration of the Project	36
22	Waterford - Lime - Final Effluent pH Levels over the Duration of the Project	37
23	Waterford - Lime - Effluent BOD Levels over the Duration of the Project	41
24	Waterford - Lime - Raw Sewage BOD Concentrations over the Duration of the Project	42
25	Waterford - Lime - Final Effluent Suspended Solids over the Duration of the Project	43
A-1	Sutton - Ferric Chloride - A Comparison of Total Phosphorus in the Raw and "Treated" Sewage	54
A-2	Sutton - Ferric Chloride - A Comparison of BOD in the Raw and "Treated" Sewage	55
A-3	Sutton - Ferric Chloride - A Comparison of Suspended Solids in the Raw and "Treated" Sewage	56
A-4	Sutton - Ferric Chloride - A Comparison of Total Nitrogen in the Raw and "Treated" Sewage	57
A-5	Sutton - Ferric Chloride - A Comparison of Organic Nitrogen in the Raw and "Treated" Sewage	58
A-6	Sutton - Ferric Chloride - A Comparison of Alkalinity in the Raw and "Treated" Sewage	59
B-1	Shelburne - Alum - A Comparison of Total Phosphorus in the Raw and "Treated" Sewage	63
B-2	Shelburne - Alum - A Comparison of BOD in the Raw and "Treated" Sewage	64
B-3	Shelburne - Alum - A Comparison of Suspended Solids in the Raw and "Treated" Sewage	65

LIST OF FIGURES (CONT'D)

Figure		Page
B-4	Shelburne - Alum - A Comparison of Total Nitrogen in the Raw and "Treated" Sewage	66
B-5	Shelburne - Alum - A Comparison of Organic Nitrogen in the Raw and "Treated" Sewage	67
B-6	Shelburne - Alum - A Comparison of the Alkalinity in the Raw and "Treated" Sewage	68
C-1	Waterford - Lime - A Comparison of Total Phosphorus Concentrations in the Raw and "Treated" Sewage	71
C-2	Waterford - Lime - A Comparison of BOD Levels in the Raw and "Treated" Sewage	72
C-3	Waterford - Lime - A Comparison of Suspended Solids Levels in the Raw and "Treated" Sewage	73
C-4	Waterford - Lime - A Comparison of pH Values in the Raw and "Treated" Sewage	74
C-5	Waterford - Lime - A Comparison of Total Nitrogen in Raw and "Treated" Sewage	75
C-6	Waterford - Lime - A Comparison of Organic Nitrogen in the Raw and "Treated" Sewage	76

LIST OF TABLES

Table		Page
1	Response of Phosphorus Levels to Dosage Changes in Lime Treatment at Waterford	39
2	Mean Bacteriological Results at Waterford	45

CONCLUSIONS

1. Ferric chloride at a dosage of 20 mg/l, when continuously added to the influent raw sewage at Sutton, maintained the lagoon effluent total phosphorus concentration below 1 mg/l. An initial batch treatment quickly brought the phosphorus to this level.
2. The alum at a dosage of 225 mg/l, when continuously added to the influent raw sewage at Shelburne, effectively reduced the lagoon effluent total phosphorus concentration to below 1 mg/l.
3. With both ferric chloride and alum there was no evidence of resolubilization of the precipitated phosphorus in the lagoons, even under anaerobic conditions.
4. The hydrated lime, when added to the raw sewage at Waterford, was not efficient at reducing the effluent total phosphorus concentration below 1 mg/l, at dosages up to 400 mg/l.
5. With the lime treatment at Waterford, the initial high pH in the "treated" sewage was not maintained over the detention time in the lagoon and resolubilization of the phosphorus occurred.
6. At all three locations there was no appreciable effect on any effluent parameters other than phosphorus except for an increase in pH with the lime treatment.
7. There were only a few mechanical problems with the ferric chloride and alum feed systems. The hydrated lime, as used here, caused many mechanical breakdowns due to scaling and equipment failure; in addition the lime application was labour intensive.

1 INTRODUCTION

The Canada-U.S. Agreement of 1972 specified that in certain areas of the Province of Ontario wastewater treatment plants were required to have an effluent total phosphorus concentration of 1 mg/l or less by the end of 1973 or 1975, depending on their location in the Province.

In many of these areas waste stabilization ponds are used for wastewater treatment. If they are operated on a fill-and-draw basis, "batch treatment" can effectively reduce the phosphorus level (Graham and Hunsinger, 1974). However, many lagoons are operated with a continuous discharge.

The purpose of this project was to determine if adding a chemical coagulant to the raw sewage as it enters the lagoon would effectively reduce the phosphorus concentration in the effluent leaving the lagoon. Three coagulants were used: alum, ferric chloride and hydrated lime. This was a long-term project of two years duration to find out: if the chemicals effectively reduce the phosphorus concentrations; the dosage required; possible effects on the other effluent parameters; if there are any adverse effect on the lagoon itself such as sludge build-up; and if any problems developed relating to each of the chemical coagulants.

Three sites were chosen for full scale phosphorus removal studies on continuous overflow lagoons. The basis for the selection was that the lagoon received mainly a domestic sewage input, and had favourable phosphorus removal from the raw sewage with at least one of the proposed chemical coagulants in jar tests. Eventually the sites selected were Sutton for ferric chloride, Shelburne for alum and Waterford for lime.

At each installation a method for storing and adding the chemical had to be devised; also the location of these facilities and point of chemical addition had to be settled upon. Jar tests had to be carried out on raw sewage samples, and a regular sampling program had to be set up.

2 FERRIC CHLORIDE - SUTTON

2.1 Methods

2.1.1 Site description and ferric chloride addition

Sutton, a town of about 2,500 people near the southern edge of Lake Simcoe, has a 16 ac (6.5 ha), 5 ft (1.5 m) deep waste stabilization pond, the effluent from which flows continuously into the Black River. Throughout most of the study the effluent flow was monitored by a 45° V-notch weir and the retention time was usually over 100 days, but could be as low as 64 days. The pond is about 3,000 ft (900 m) from the pumping station which is located near the middle of town. It was decided to put the chemical addition facilities adjacent to the pumping station and to inject the chemical into the forcemain a short distance from the pumps (Figure 1). A 5,000 gal (22,750 l) insulated fibreglass storage tank was placed on a temporary pad of plywood and packed sand. A small shed was built on the corner of the pad to protect the valve and heater connections to the tank and house the chemical feed pump. The feed pump was electrically synchronized with the raw sewage pumps to operate when either pump was working. These pumps normally run on an alternating cycle and are controlled by the level in the wet well. If the level is high enough it will activate both pumps. Since this was never observed to happen, only a single chemical feed rate was required. To measure the chemical feed rate an inline flow meter with a "Hastelloy C" float was used.

The ferric chloride was added to the sewage through a plastic hose leading to a plastic injection point in the asbestos cement forcemain about 5 ft (1.5 m) after the sewage pumps. The treated sewage then flowed 3,000 ft (900 m) to a distribution box on the side of the lagoon, and then to a subsurface discharge point in the middle of the pond.

A program was set up to sample the raw sewage, the chemically treated raw sewage ("treated" sample) and the effluent from the lagoon. To get the raw sewage sample, grab samples were taken from a valved outlet between the sewage pumps and the point of chemical addition. Later in the study a 24-hr composite sampler was used. "Treated" samples were taken in order to ascertain the initial effects on the raw sewage of the chemical shortly after it entered the lagoon, and in this way to separate the

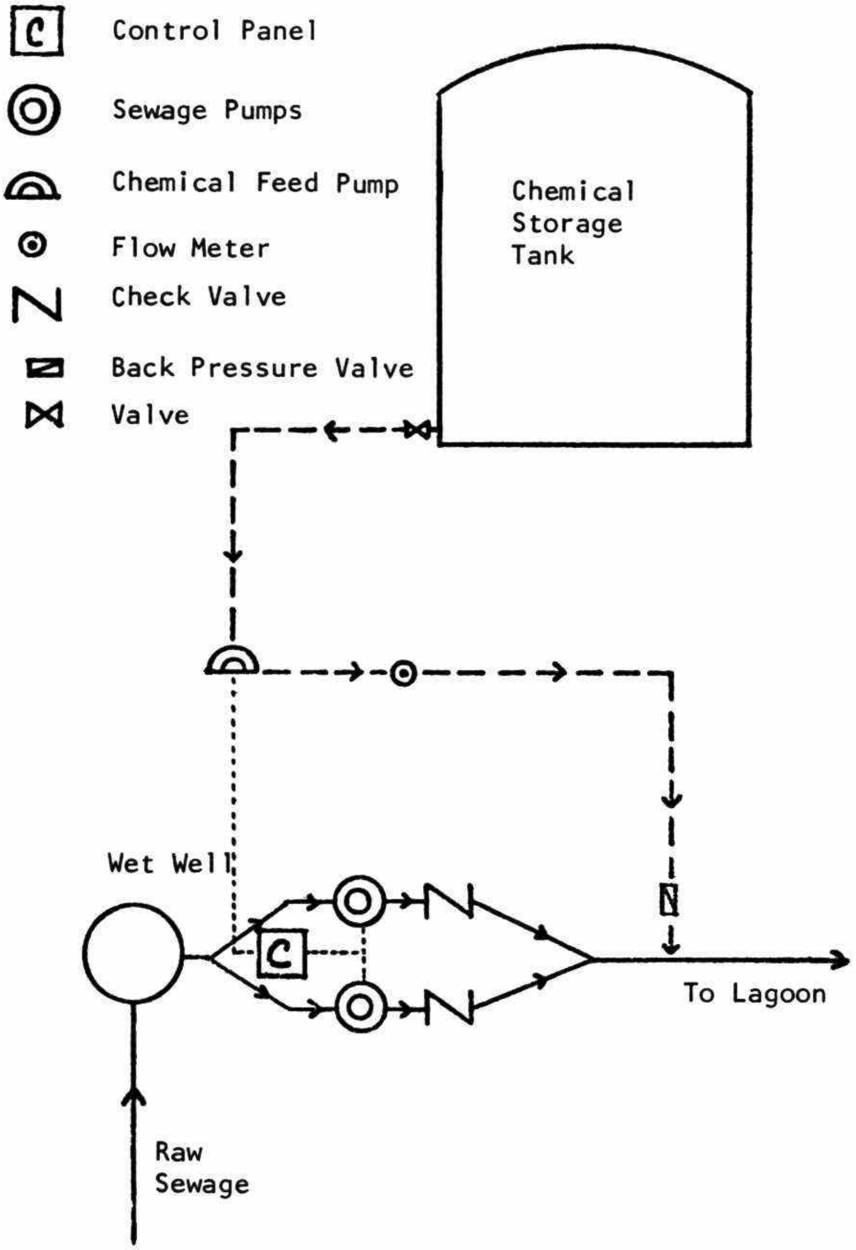

FIGURE 1. FERRIC CHLORIDE FEED SYSTEM AT SUTTON

immediate action of the chemical and the subsequent behaviour of the parameters over the retention time in the lagoon. The "treated" samples were taken at an overflow weir at the end of the forcemain beside the lagoon. The chemical and the raw sewage were by this time well mixed. These samples were taken with a bucket and the contents were allowed to settle for an hour; at that time the supernatant was decanted into the sample bottles. The effluent samples were taken from the effluent chamber.

2.1.2 Jar tests and dosage

Prior to chemical addition, six grab samples of raw sewage were taken over a three-month period and jar tested with various dosages of ferric chloride. These mixtures were subjected to 5 minutes fast mix (200 rpm), 15 minutes slow mix (30 rpm) and 1 hour of settling. The supernatant was then analyzed for total and soluble phosphorus, alkalinity and pH.

As can be seen in Figure 2 there was a good reduction of the total phosphorus concentration. The initial dosage chosen was 30 mg/l as Fe^{+3}, which should have reduced the total phosphorus concentration in the raw sewage to about 1.5 mg/l. It was thought that the lagoon would reduce the level further to below 1 mg/l. The chemical addition was started in late November, 1972.

It was decided to "batch treat" the lagoon to immediately reduce the total phosphorus levels below 1 mg/l (Graham and Hunsinger, 1974). Samples of the lagoon contents were jar tested with ferric chloride and the required dosage was found to be 20 mg/l as Fe^{+3}. The lagoon was "batch treated" on November 30, 1972 when the continuous chemical addition system was operating.

The initial dosage of 30 mg/l was based on the rated sewage pump output of 700 Igpm (3,180 l/m), but when the sewage pump output was measured as the height of liquid flowing over the weir in the influent structure beside the lagoon, it was found to be only 500 Igpm (2,275 l/m). Based on the 500 Igpm flow the ferric chloride dosage had been 42 mg/l as Fe^{+3} and in mid-February, 1973, it was reduced to 30 mg/l as Fe^{+3}. The dosage to the raw sewage was continuous at this level until June 4, 1974, when it was reduced to 20 mg/l. This part of the study was completed

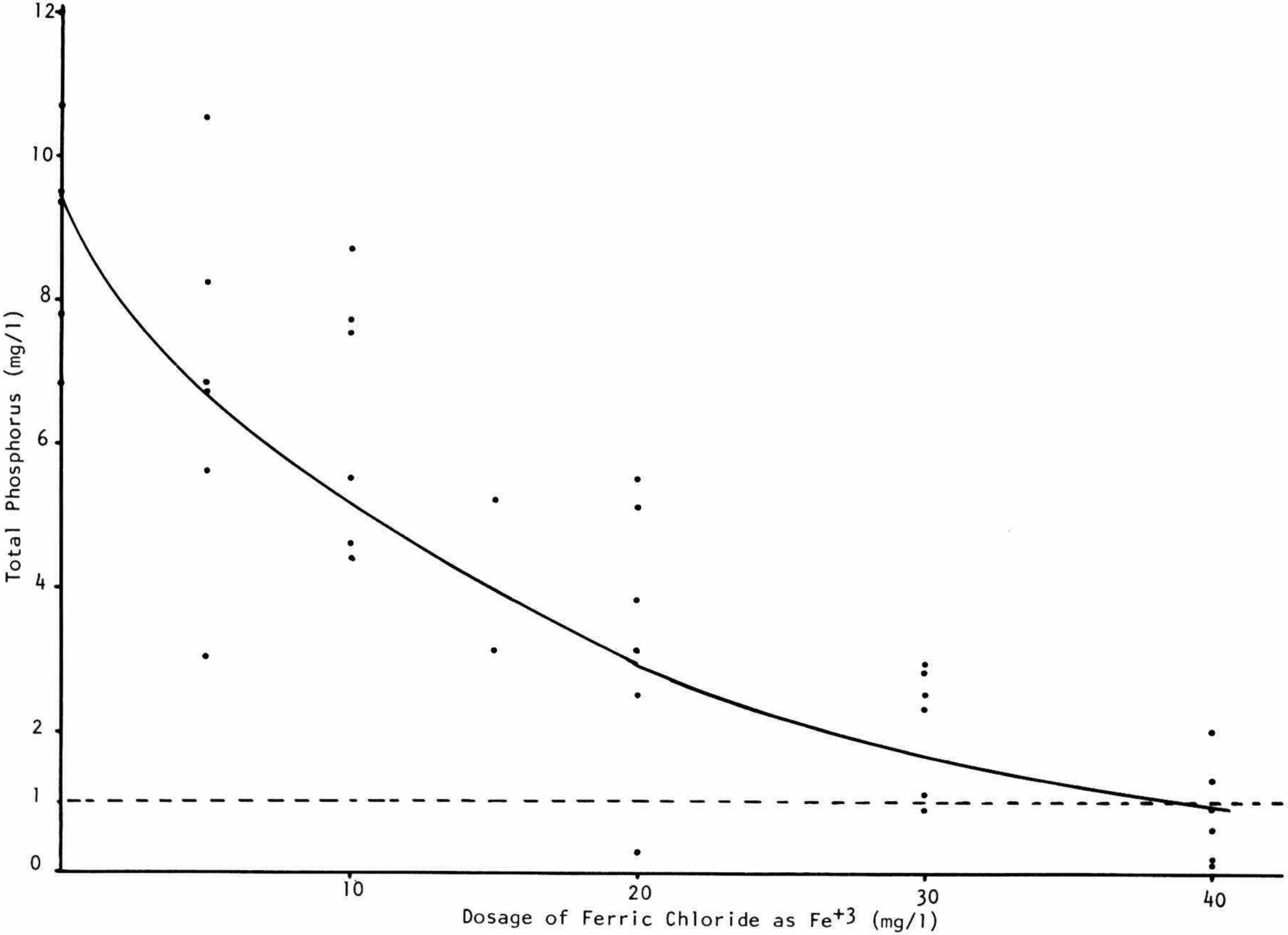

FIGURE 2. SUTTON - FERRIC CHLORIDE JAR TEST RESULTS

at the end of November, 1974, although the chemical addition was continued by the municipality since phosphorus removal was required at this location.

2.1.3 Sediment build-up

An attempt was made to estimate the sediment build-up that occurred during the addition of the ferric chloride. The measurement to the upper surface of the sediment was obtained with a "portable sludge level detector" while distance to the pond bottom was determined by pushing a 5 inch (13 cm) disk, on the end of a pole, as far down as possible. The difference was assumed to be the sediment thickness.

2.2 Results and Discussion

At the Sutton lagoon the "batch treatment" with ferric chloride was very effective in quickly reducing the total phosphorus concentration in the lagoon to below 1 mg/l (Figure 3). The level continued to decrease for the next two months. For the remainder of the study, with rare exceptions, the effluent total phosphorus concentration remained below 1 mg/l. During the winters the level was low and stable, while from April to October, the biologically productive period for the lagoon, the level was more variable.

The dissolved oxygen in the lagoon was measured only once when the lagoon was ice covered, and it was below 0.5 mg/l near the sediment. There was no increase in effluent phosphorus as might be expected if the phosphorus in the sediment resolubilized under anaerobic conditions.

After the dosage was decreased to 20 mg/l as Fe^{+3} in June, 1974, the total phosphorus concentration did not increase above the maximum levels that occurred in 1973. But the levels in the fall of 1974 were higher than in the fall of 1973, suggesting that the dosage of 20 mg/l as Fe^{+3} is probably approaching the optimum to reduce the total phosphorus to just below 1 mg/l at Sutton.

Ferric chloride was very effective at reducing the total phosphorus concentration in the raw sewage at Sutton. This is best demonstrated by the plot of the total phosphorus concentration in the raw sewage against the total phosphorus concentration in the "treated" sewage shown in Figure A-1, Appendix A. There was a reduction in the "treated" samples, usually to below 1 mg/l.

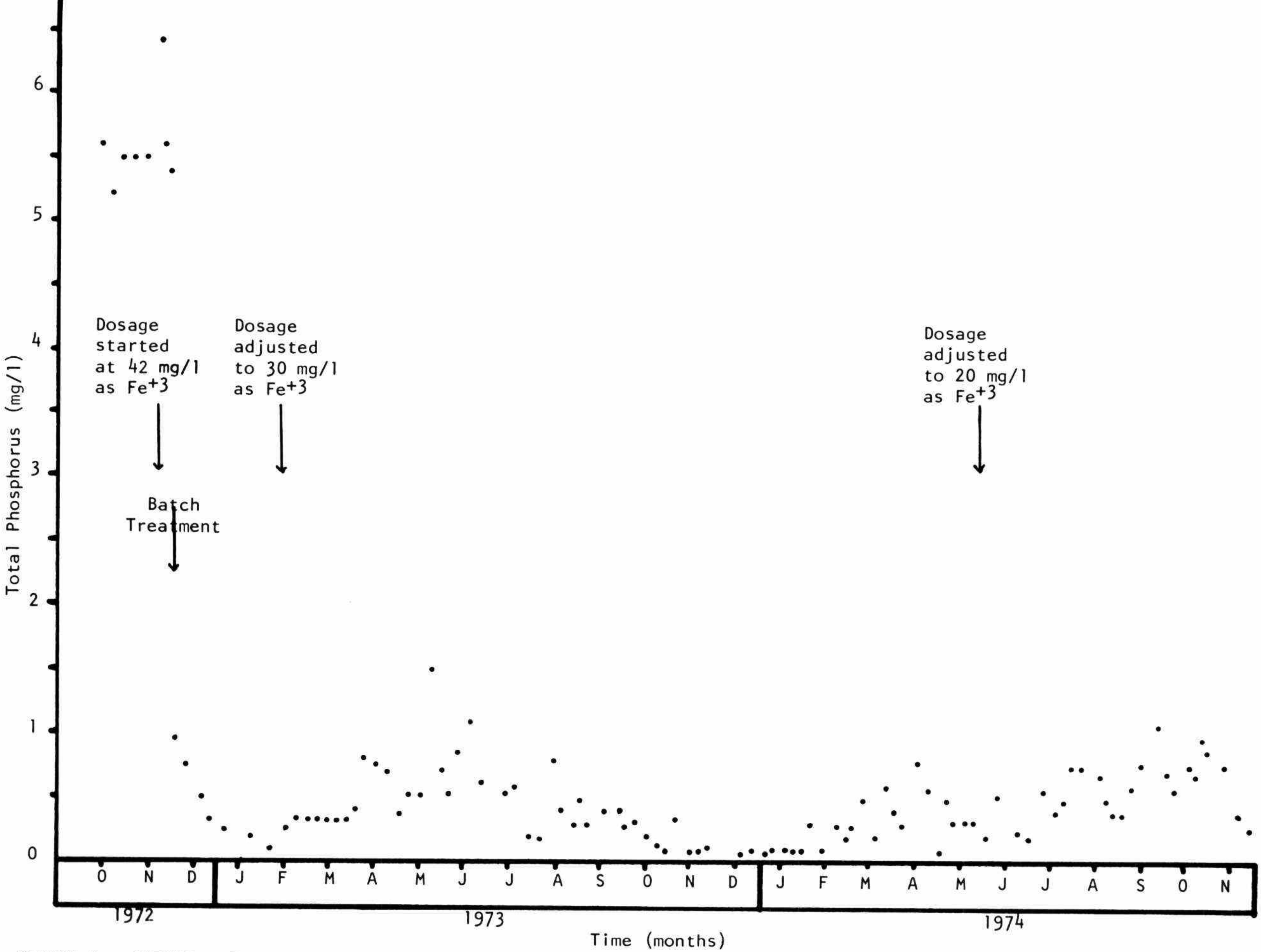

FIGURE 3. SUTTON - FERRIC CHLORIDE - EFFLUENT TOTAL PHOSPHORUS OVER THE DURATION OF THE PROJECT

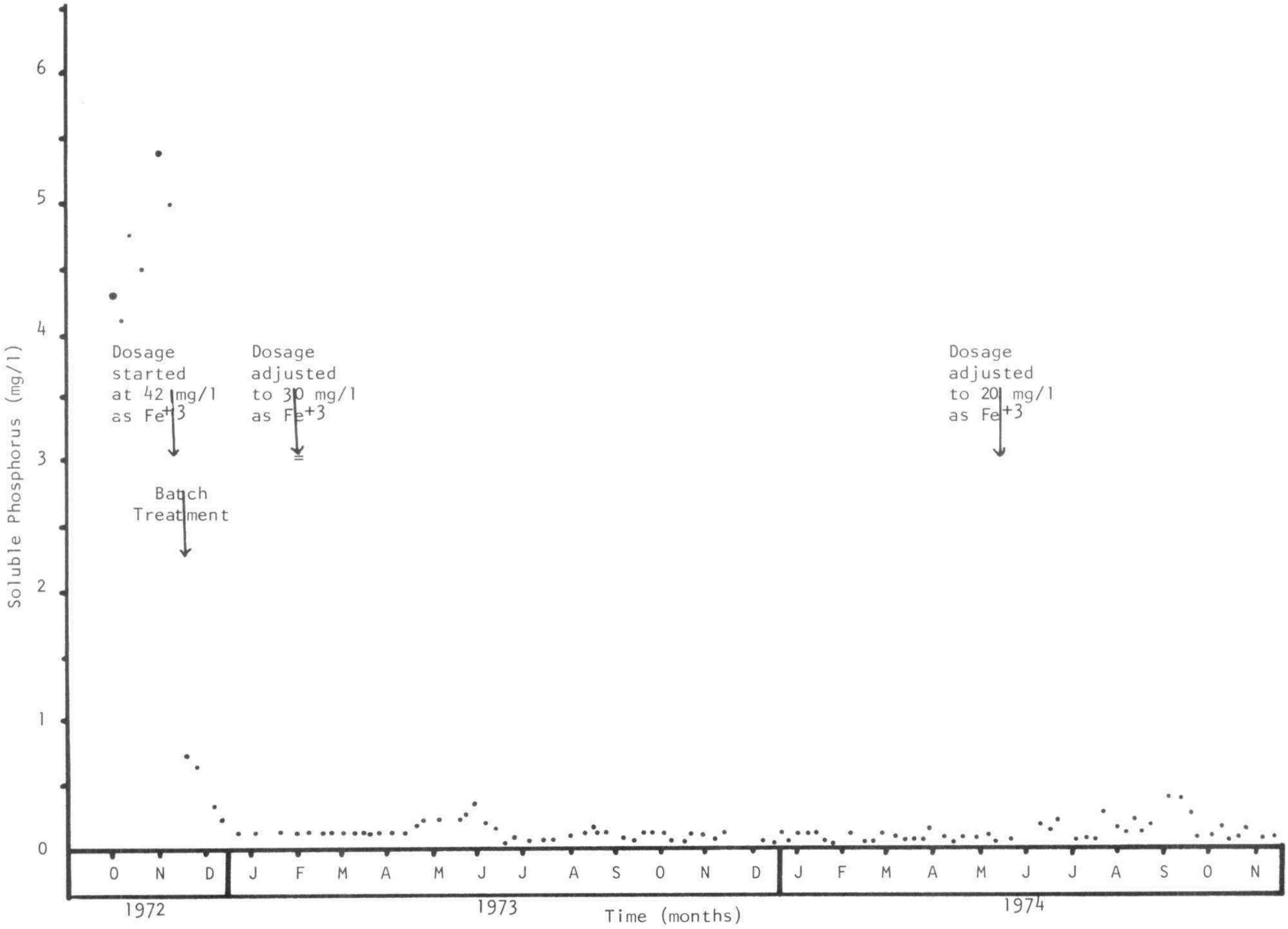

FIGURE 4. SUTTON - FERRIC CHLORIDE - EFFLUENT SOLUBLE PHOSPHORUS OVER THE DURATION OF THE PROJECT

As can be seen in Figure 4, the "batch treatment" drastically reduced the soluble phosphorus in the lagoon. The level remained at that low level for the duration of the project. The variations in the dosage had no apparent effect on the soluble phosphorus.

Although the soluble phosphorus was relatively low, it was never below 0.01 mg/l, the level considered by Sawyer, 1947 (See Mackenthun, 1965) to be the minimum level to cause nuisance algae blooms. There were blooms in the Sutton lagoon but they were never a problem, although they seemed to cause slight increases in the effluent total phosphorus concentration.

The ferric chloride was very effective in initially precipitating the BOD in the sewage entering the lagoon (Figure A-2, Appendix A). The average effluent BOD in the five years prior to this experiment (MOE Project Operations Summaries) was 17 mg/l, which is above the mean of 10.7 mg/l during the treatment. However, the pretreatment samples in the fall of 1972 (Figure 5) are essentially the same as in the fall of 1973 during treatment. It appears that the treatment with ferric chloride slightly reduced or had little effect on the effluent BOD.

A similar situation occurred with the suspended solids concentration. In the "treated" sewage entering the lagoon, the suspended solids concentrations were drastically reduced (Figure A-3, Appendix A). The average effluent suspended solids level in the five years prior to the start of chemical treatment (MOE Project Operations Summaries) was 28 mg/l. During the treatment the mean value was 21 mg/l. The suspended solids concentrations just before treatment were below most of the values during the treatment (Figure 6). Therefore, the chemical treatment probably had no effect on the effluent suspended solids concentrations.

As expected both iron and chloride were higher in the lagoon effluent during treatment. The chlorides were about 120 mg/l in the pretreatment samples, increased to about 230 mg/l during most of the treatment, then dropped to about 160 mg/l when the dosage was decreased on June 4, 1974. Similarly, with the iron it was usually below 1 mg/l prior to treatment; during the first winter of treatment, there was a marked increase to levels from 2.5 to 5.9 mg/l, while during the rest of the treatment period the values were usually between 1.0 and 2.5 mg/l,

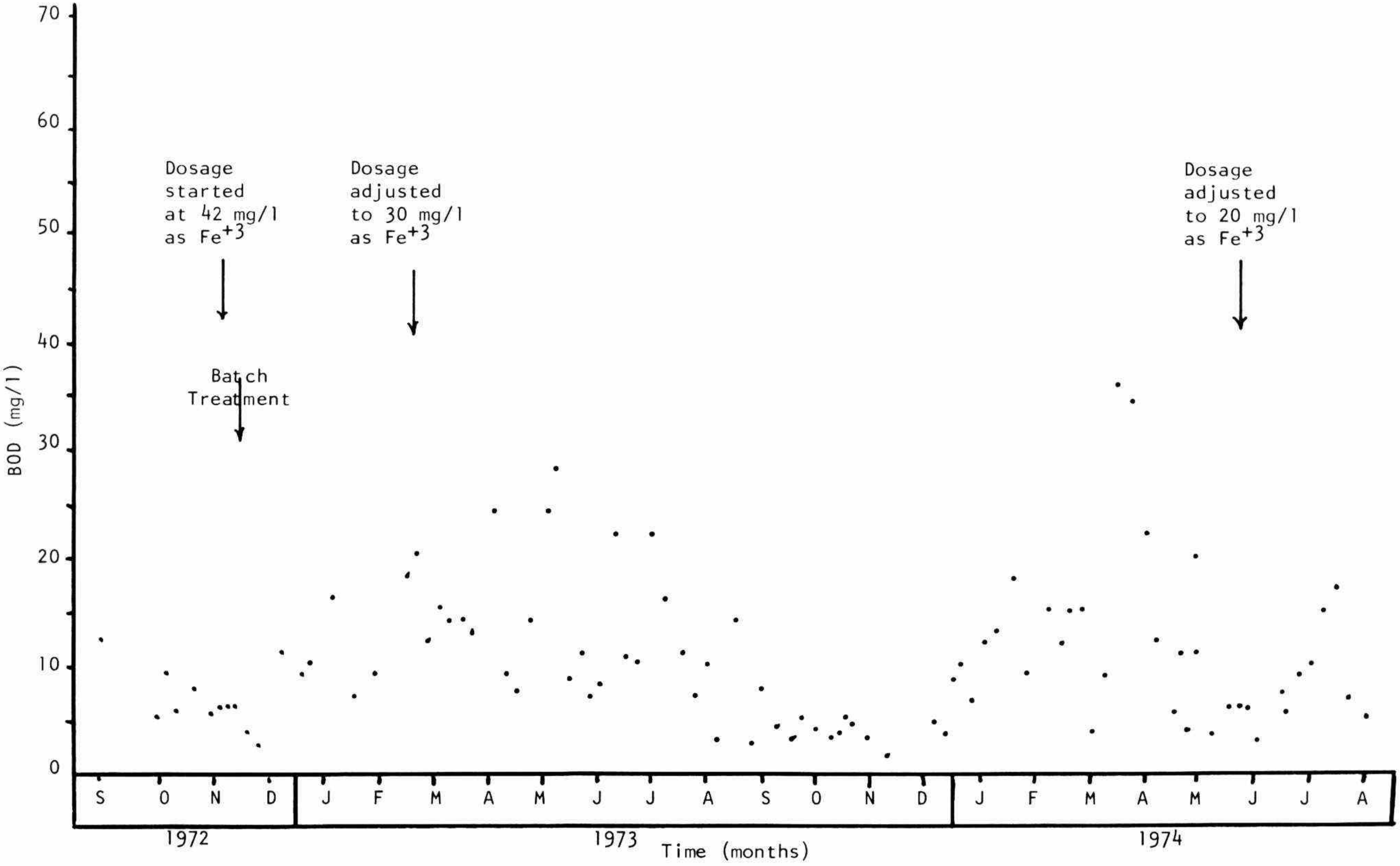

FIGURE 5. SUTTON - FERRIC CHLORIDE - FINAL EFFLUENT BOD OVER THE DURATION OF THE PROJECT

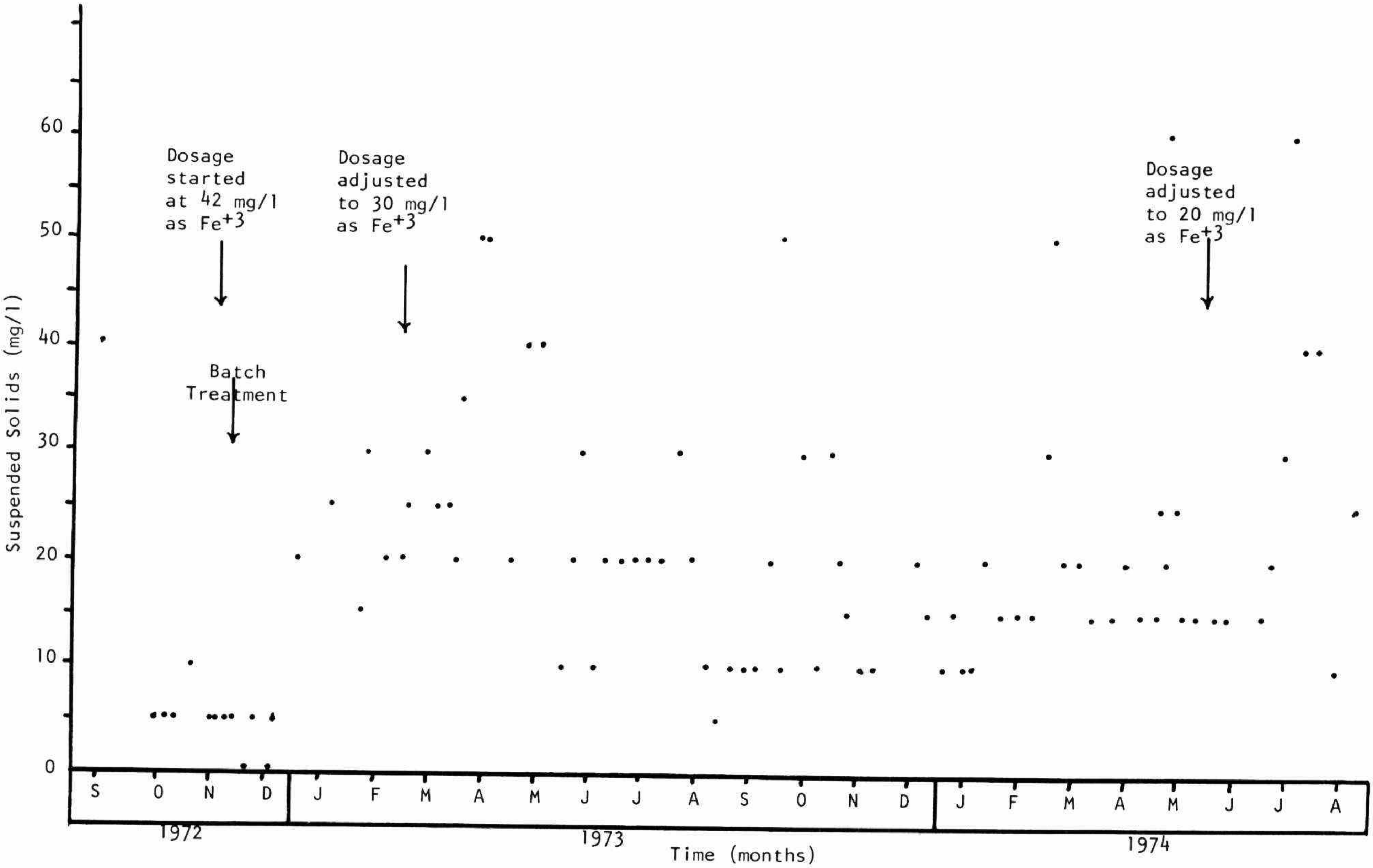

FIGURE 6. SUTTON - FERRIC CHLORIDE - FINAL EFFLUENT SUSPENDED SOLIDS OVER THE DURATION OF THE PROJECT

except for a peak during March and April in 1973 when it increased to between 3 and 5 mg/l.

Other effluent parameters were examined such as total Kjeldahl nitrogen, nitrate, nitrite, free ammonia, pH, alkalinity, hardness, dissolved solids and bacteria, but in all cases there was no apparent difference between the pre- and post-treatment samples. The total and organic nitrogen and alkalinity in the raw sewage were compared with the values in the "treated" sewage (see Appendix A): there was no effect of the chemical treatment on the total nitrogen concentrations, a slight reduction in the organic nitrogen levels, and a noticeable reduction in the alkalinity.

Two sediment depth surveys were conducted in 1974, one in February and the other in May. It was hoped to determine the rate of accumulation over this period. In the first survey the heap around the influent pipe was about 100 ft (30 m) in diameter with the height gradually rising to a central depth of 2½ - 3 ft (0.7 - 0.9 m). The sediment depth over the rest of the lagoon ranged from 1 to 4½ in (2.5 to 11 cm). The sediment had accumulated in over one year of chemical addition plus an unknown time previous to this period.

In the second sediment survey, three months later, there was no measurable difference in the amount of sediments using the technique outlined in the methods section.

2.3 Mechanical Problems

After several months of chemical treatment, there was corrosion of the brass check valve seats. The cause was traced to a momentary negative pressure when the sewage pump stopped pumping, which was sufficient to pull a slug of ferric chloride into the main. Any material holding the check valves partially opened would allow the concentrated chemical to flow back through the valves into the wet well. To rectify the situation a back pressure valve (15 psi) was installed on the chemical feed line just before the injection point into the main. At this time, new check valves were installed, and after several months of operation there was no sign of corrosion even though foreign material was causing some leakage.

3 ALUM - SHELBURNE

3.1 Methods

3.1.1 Site description and chemical addition

Shelburne has a population of about 1,600 and is located in the middle of Dufferin County. It has two sewage lagoons of 6.6 ac (2.8 ha), each with a depth of 3 ft (0.9 m) that are operated in parallel and discharged continuously into the Boyne River. The raw sewage flows to the pumping station, which is located about 1,000 ft (300 m) from the lagoons.

In a previous study (Ehlert, 1972) alum was added to the east lagoon with the raw sewage. A dosage of 170 mg/l was added continuously for a period from June, 1971 until September, 1972 and intermittently until the present study began.

In the present study alum was stored in a 5,000 gal (22,750 l) fibreglass tank located beside the pumping station (Figure 7). A steel shed beside the tank was used to house the chemical feed pumps and composite sampler. The sewage pumps operated in a similar fashion to those at Sutton in that if the level in the wet well was high enough both pumps would operate. Since this was a common occurrence at Shelburne it was advisable to have two chemical feed pumps, each activated by one of the sewage pumps. The chemical feed rate was measured by inline flow meters. Back pressure valves were installed just before the injection points which were located in the top of the check valves after each sewage pump.

The flows out of each lagoon were measured by 22.5° V-notch weirs in each effluent structure. During the study the retention times in the west cell ranged from 31 to 104 days, and in the east cell ranged from 18 to 45 days. At times, these cells were grossly overloaded.

The sampling program was identical to that at Sutton.

3.1.2 Dosage

Shelburne was previously being used to test alum addition to a continuous overflow lagoon (Ehlert, 1972). When this project ended the dosage being used was 170 mg/l, and the effluent total phosphorus concentration from the treated (east) cell was about 2.5 mg/l, which did achieve the objective of 80% removal for that program. In an effort to reduce the

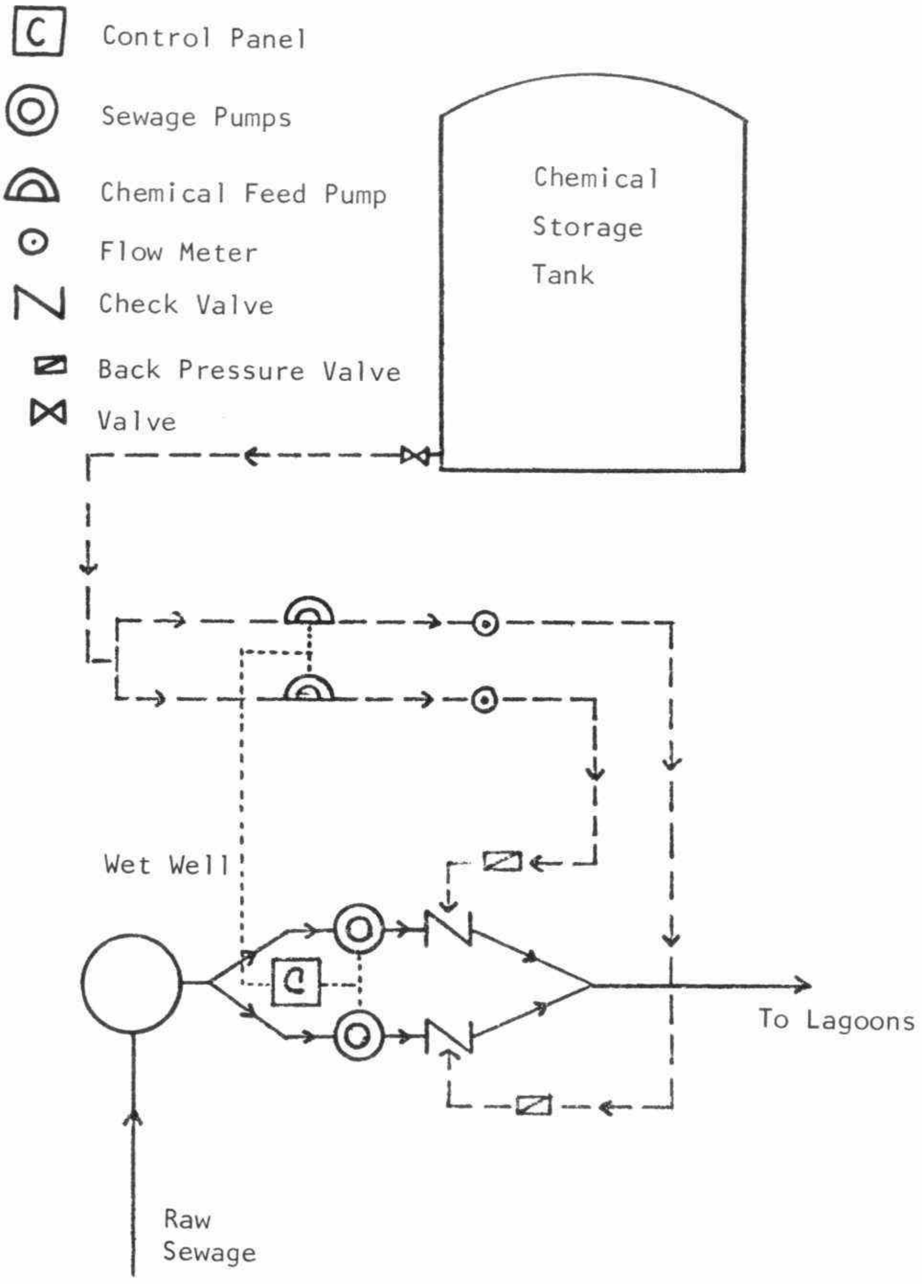

FIGURE 7. ALUM FEED SYSTEM AT SHELBURNE

total phosphorus concentration below 1 mg/l, the dosage of alum was increased to 200 mg/l. This dosage was based on a sewage pump output of 208 Igpm (946 l/m).

There was some intermittent alum addition to the east cell through January and February, 1973. Alum feed to both cells at a dosage of 200 mg/l was initiated at the end of February, but due to start-up problems it was impossible to maintain a continuous feed until the end of May.

This dosage rate was maintained until mid-October, 1973, when it was increased to 225 mg/l. It was continued at this level until this portion of the study was completed at the beginning of June, 1974.

3.2 Results and Discussion

The effluent total phosphorus from the Shelburne lagoons at the start of this project was lower from the east cell (Figure 8), averaging about 2.5 mg/l, compared with the west cell (Figure 9) where it ranged between 3.5 to 7.5 mg/l. This was because the raw sewage entering the east lagoon was being treated with alum prior to the present study at a dosage of 170 mg/l while the west lagoon was untreated. When the alum feed in the present study was initiated, there was a rapid decrease in the effluent total phosphorus to below 1 mg/l in both cells. This was due to the short retention times. In mid-May, 1973, treatment was stopped as the storage tank was emptied so that it could be repaired. This caused a marked increase in the effluent total phosphorus concentration from the east lagoon. As the influent pipe to the west lagoon was blocked at that time it was not affected. The total phosphorus concentration in the east lagoon returned to about 1 mg/l shortly after the alum feed started again.

In the summer of 1973, there was an increase in the total phosphorus concentrations in both cells that reached a peak of about 2 mg/l in September. This peak coincided with low flows out of both lagoons and high lagoon temperatures, which produced an increase in biological activity and probably accounts for the increased phosphorus concentrations in the effluent. A bloom of *Microsystis* occurred in the west cell during this period.

As can be seen in Figure B-1, Appendix B, the alum was efficient in reducing the total phosphorus concentration in the raw sewage. While

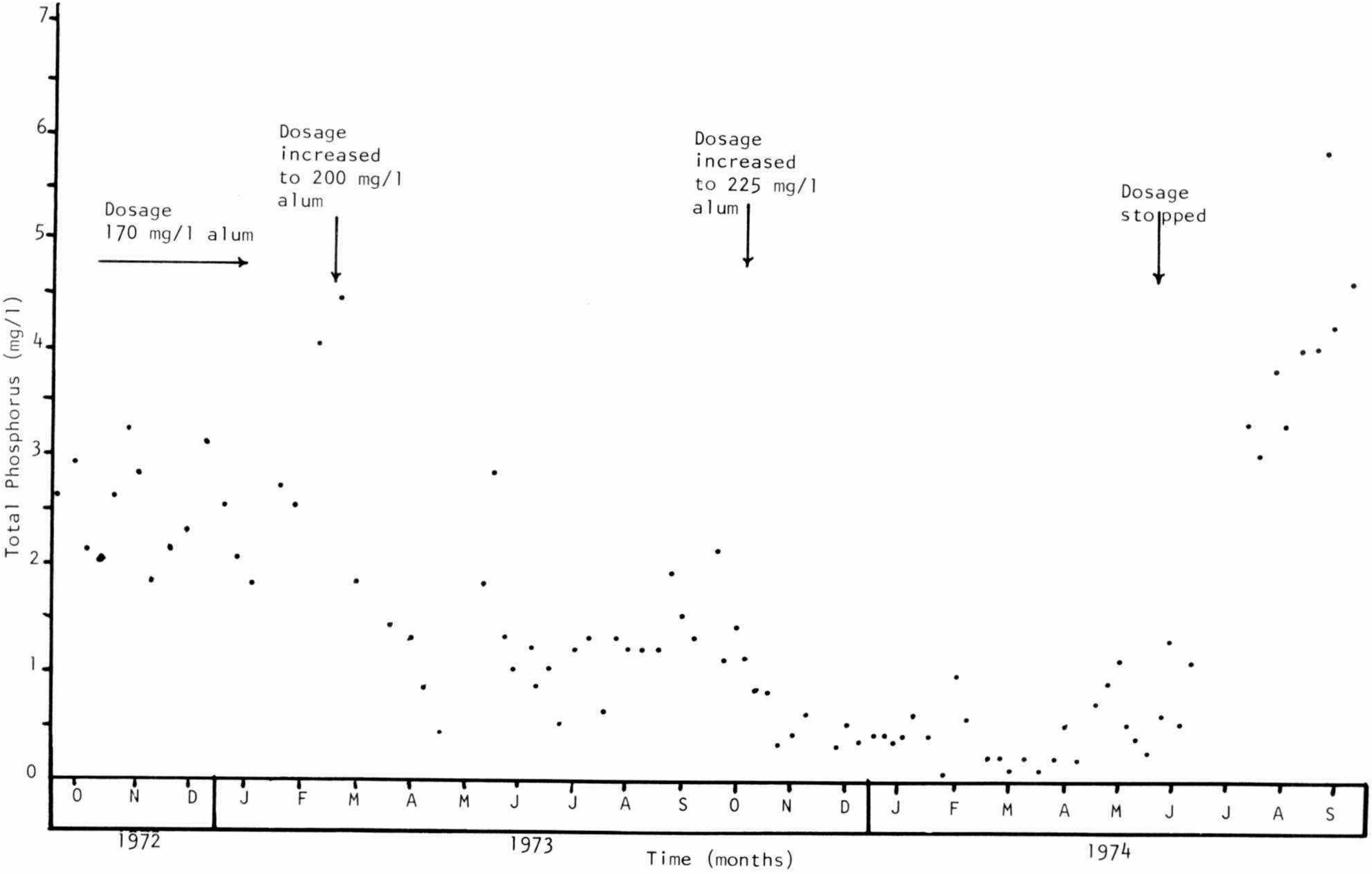

FIGURE 8. SHELBURNE - ALUM - EAST CELL FINAL EFFLUENT TOTAL PHOSPHORUS OVER THE DURATION OF THE PROJECT

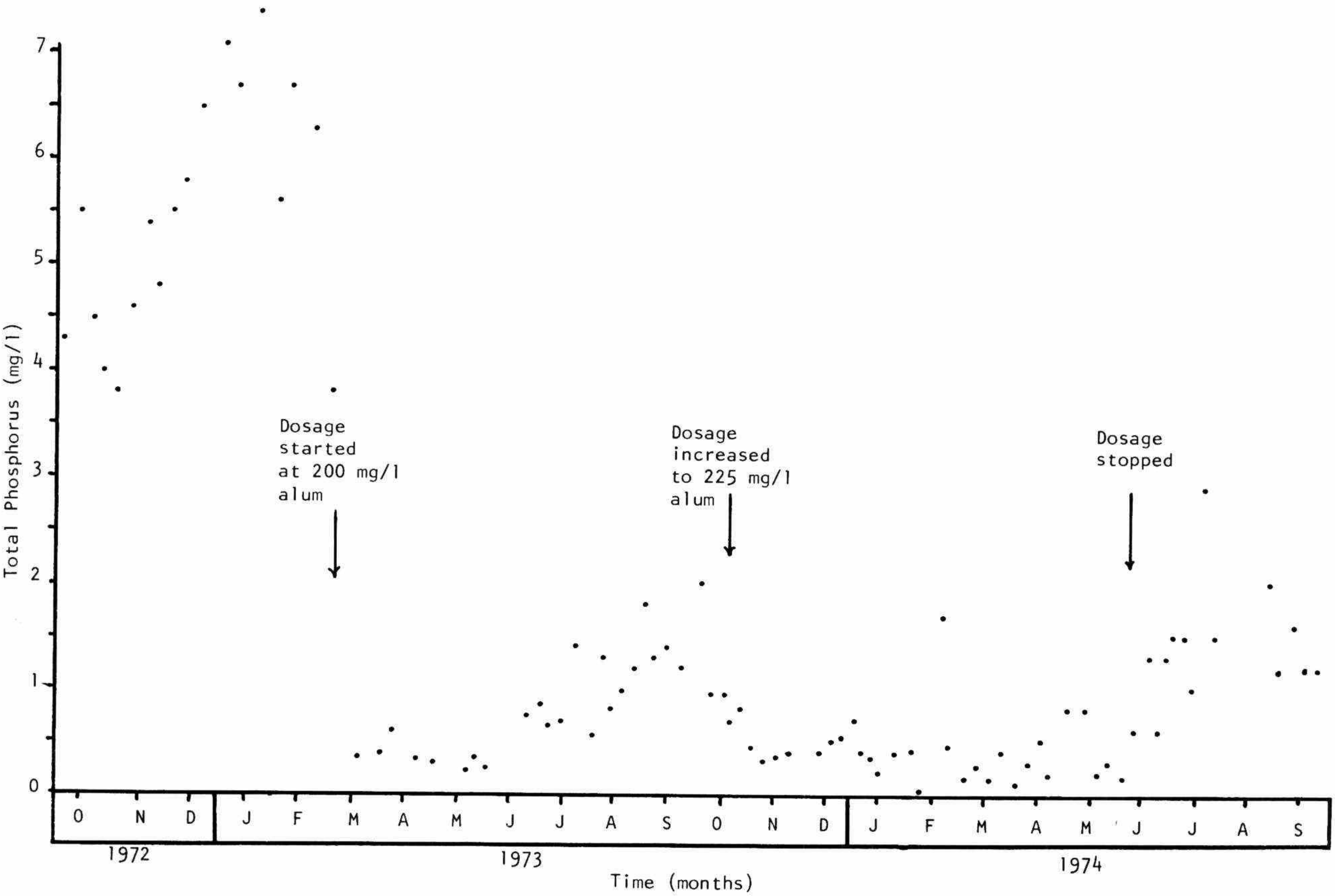

FIGURE 9. SHELBURNE - ALUM - WEST CELL FINAL EFFLUENT TOTAL PHOSPHORUS OVER THE DURATION OF THE PROJECT

the dosage was 200 mg/l, the treated raw sewage had an average total phosphorus level of 2.8 mg/l. After the dosage was increased to 225 mg/l the average total phosphorus concentrations in treated raw sewage decreased to 1.3 mg/l, and because of the short retention times the effluent total phosphorus concentrations rapidly decreased. Even with short retention times, averaging about 28 days in the east cell and 47 days in the west cell, the lagoons were usually able to reduce the phosphorus levels to below 1 mg/l. Possibly with longer retention times a lower dosage would achieve the same effluent phosphorus level.

There was a slight increase in the effluent phosphorus concentrations in February, 1974 due to a blocked chemical feed line. Again in May, there was another increase in the effluent phosphorus concentrations which coincided with a heavy algae bloom of *Chlorella* in both cells, although in this case there was just one value above 1 mg/l. During this bloom period filtered effluent samples had a much lower total phosphorus concentration, indicating that the increase in effluent phosphorus levels was due to phosphorus in the algae. The effluent total phosphorus had returned to well below the objective maximum value of 1 mg/l by the time the chemical feed was discontinued in June, 1974. When the treatment stopped the total phosphorus concentration in both cells rapidly increased to just above 1 mg/l. In June the east cell was drained and the sludge mound spread over the bottom of the lagoon. All of the sewage flow was diverted to the west cell which maintained an effluent phosphorus level usually below 2 mg/l. When the east cell was again operational in August the effluent phosphorus levels were between 3 and 5 mg/l, considerably higher than in the undisturbed west cell, pointing out the residual effect of the chemical treatment.

The results of the effluent soluble phosphorus are presented in Figures 10 and 11. Most of the phosphorus prior to treatment was in the soluble form; after the chemical addition was initiated the levels dropped to well below 1 mg/l and remained there except when the chemical feed was temporarily off (May, 1973; February, 1974).

The increase in the total phosphorus concentration during treatment did not contain significant soluble portions, which indicates that there was not a significant resolubilization of the phosphorus from the sediments even when the ponds were anaerobic and ice-covered.

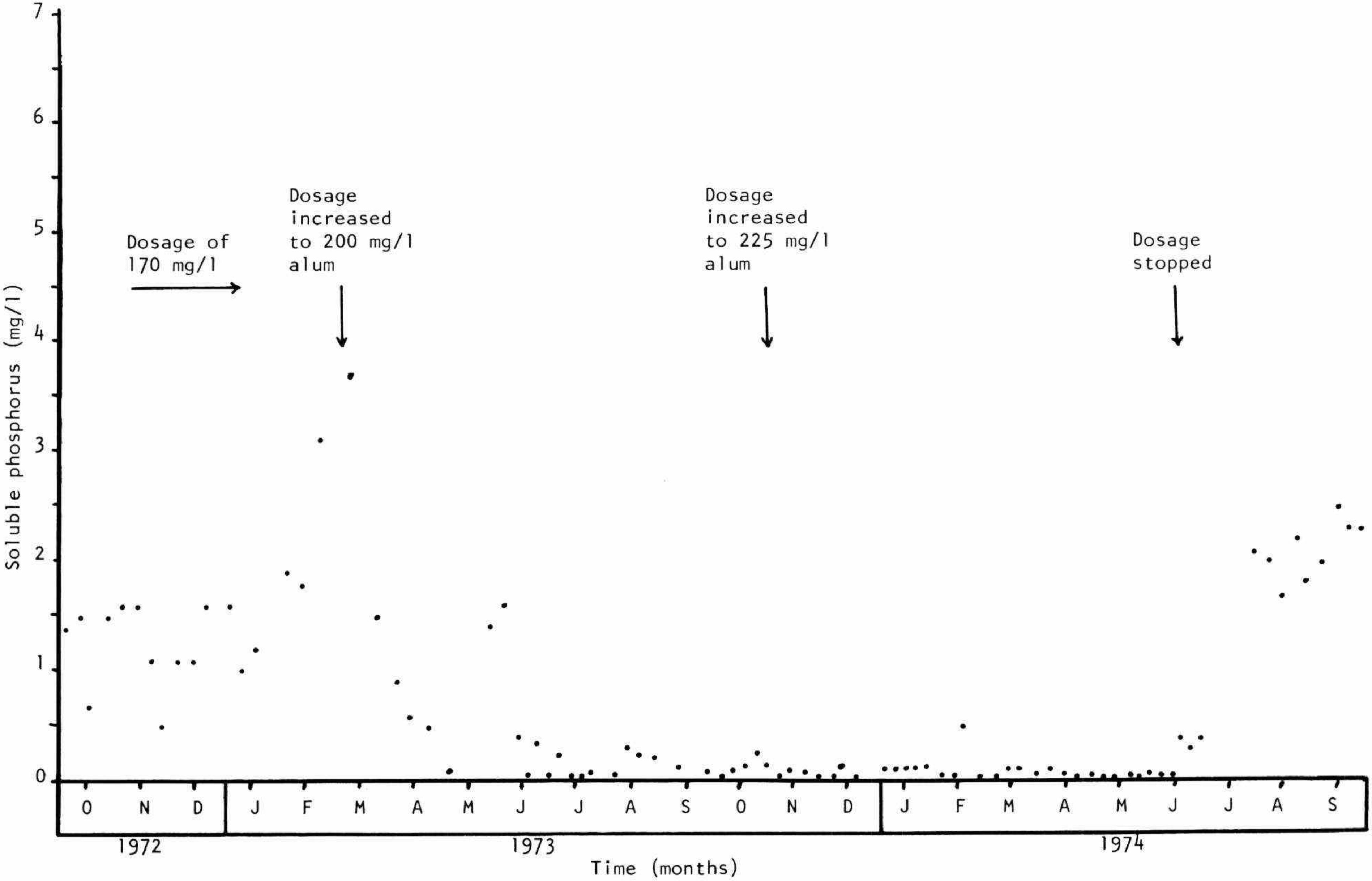

FIGURE 10. SHELBURNE - ALUM - EAST CELL FINAL EFFLUENT SOLUBLE PHOSPHORUS OVER THE DURATION OF THE PROJECT

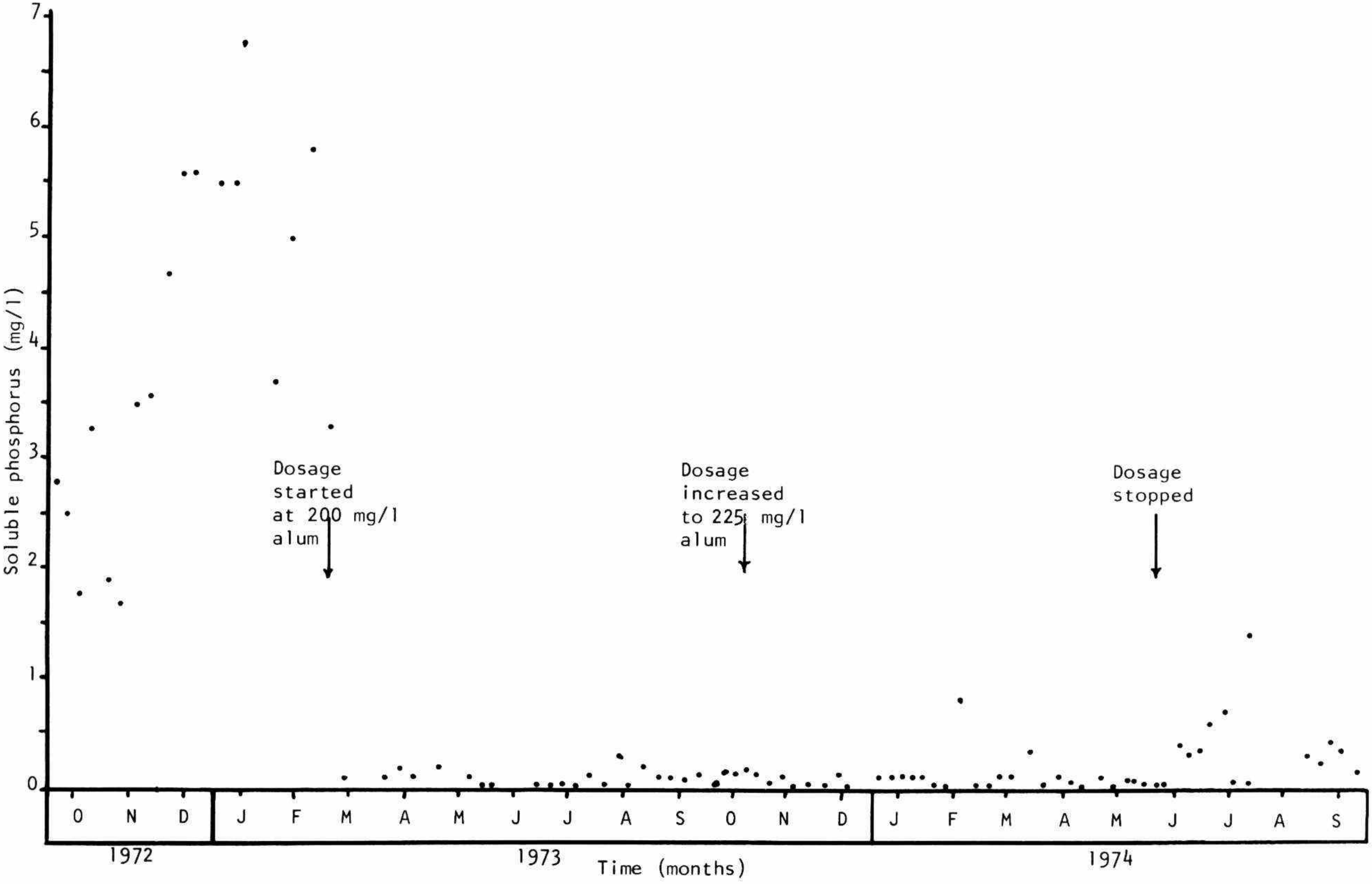

FIGURE 11. SHELBURNE - ALUM - WEST CELL FINAL EFFLUENT SOLUBLE PHOSPHORUS OVER THE DURATION OF THE PROJECT

After the chemical addition was discontinued in the west cell the soluble phosphorus remained below the levels found in the east cell after it was drained and refilled, again pointing to the residual effects of the treatment on the cell contents.

The BOD in the raw sewage was reduced somewhat by the alum addition (Figure B-2, Appendix B). After the treatment was initiated there was a gradual reduction in the effluent BOD (Figures 12 and 13). This was followed by an increase during the summer of 1973, but it was again reduced when the dosage was increased, apparently indicating a cause and effect relationship. However, the variation in the effluent BOD, although not as great, is remarkably similar to that in Waterford (Figure 23), where the BOD decreases did not correspond with the lime dosage increases. In the four years prior to any treatment (MOE Project Operations Summaries) the average BOD was 24 mg/l, which is very similar to the average BOD during the treatment of 28 and 25 mg/l for the east and west lagoons, respectively. Therefore, it appears as if the effect of alum addition on the effluent BOD was minimal when compared with the seasonal variation.

The suspended solids concentrations in the raw sewage were reduced by the alum to considerably below 100 mg/l (Figure B-3, Appendix B). In the pond effluents the levels were also below 100 mg/l, but showed a fluctuation with the seasons (Figures 14 and 15). The maxima occurred during the summer period and the minima during the spring. In the four years prior to any treatment (MOE Project Operations Summaries) the average suspended solids concentration was 43 mg/l, slightly above the average values during the treatment of 34 and 28 mg/l for the east and west lagoons, respectively. The alum addition and dosage changes did not appear to alter the pattern of the fluctuation.

As would be expected, both the aluminum and the sulphate increased in the lagoon effluents after the start of chemical treatment. The average pretreatment aluminum level in the west lagoon was 0.24 mg/l. Taking into account the retention time, the average effluent aluminum levels during the 200 mg/l alum dosage were 0.77 and 0.41 mg/l in the east and west lagoons, respectively. During the 225 mg/l alum dosage the average effluent aluminum levels were 0.69 and 0.83 mg/l in the east and west lagoons, respectively. In the four month period (approximately 3 - 4 retention

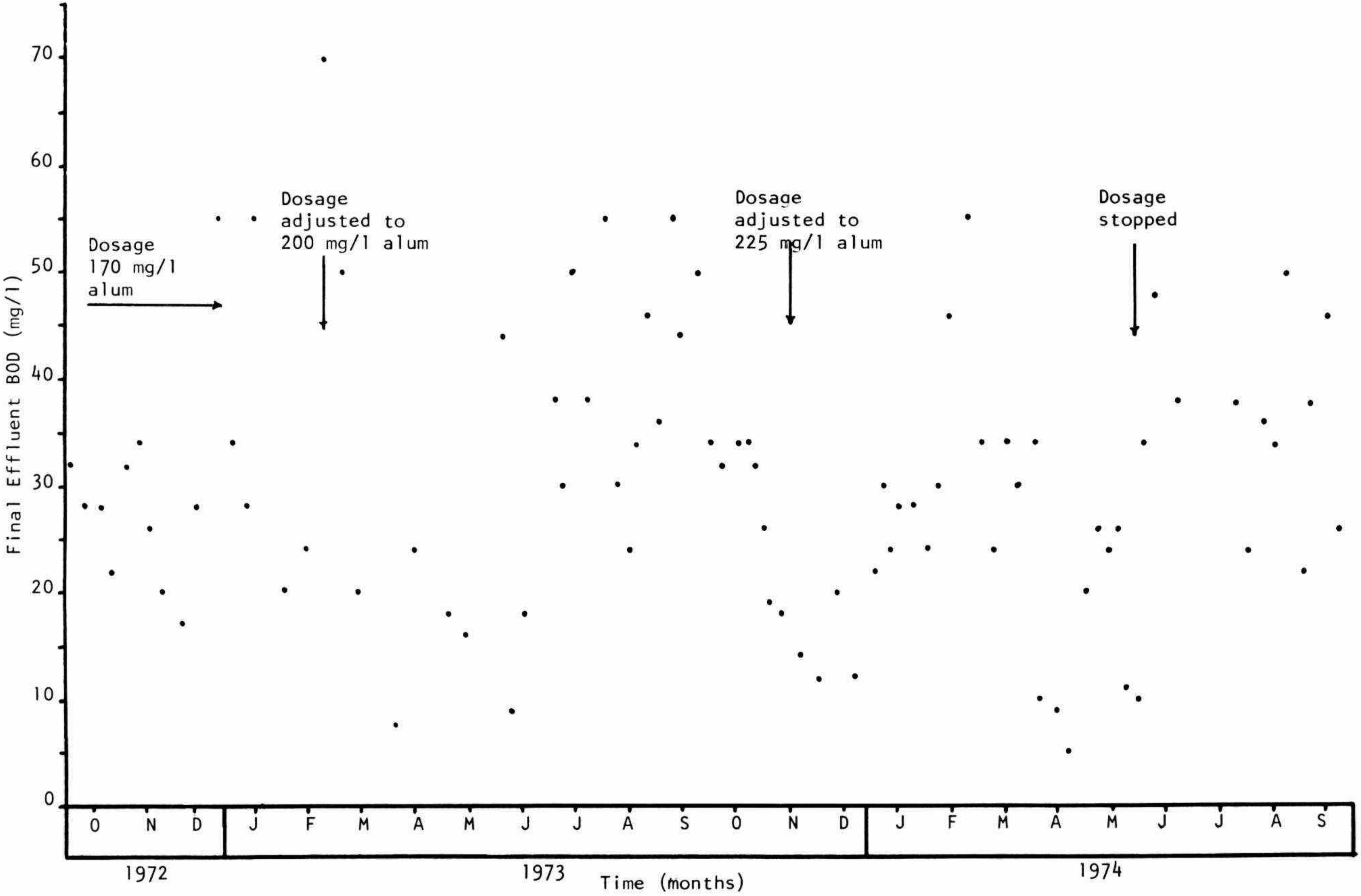

FIGURE 12. SHELBURNE - ALUM - EAST CELL FINAL EFFLUENT BOD OVER THE DURATION OF THE PROJECT

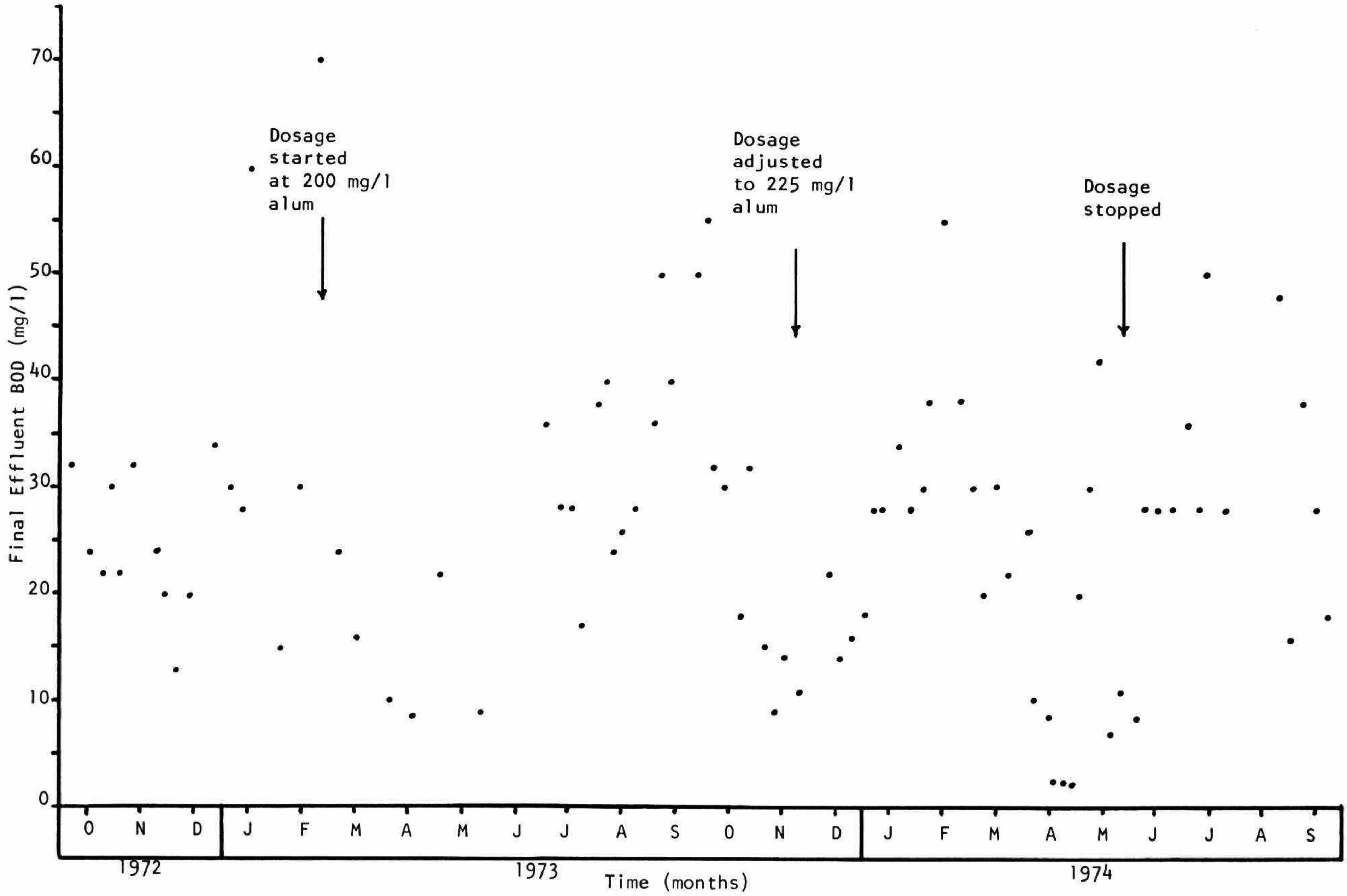

FIGURE 13. SHELBURNE - ALUM - WEST CELL FINAL EFFLUENT BOD OVER THE DURATION OF THE PROJECT

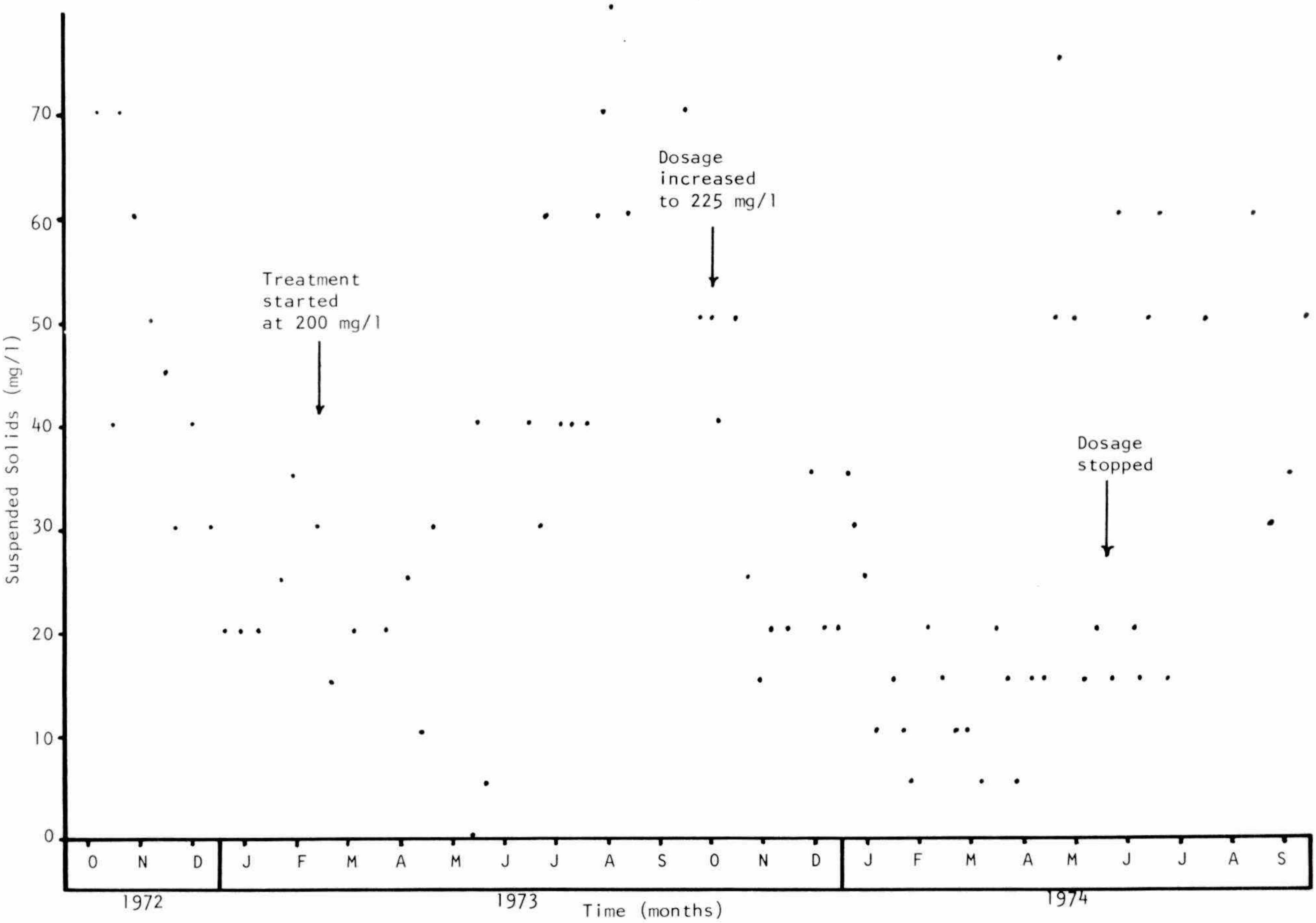

FIGURE 14. SHELBURNE - ALUM - EAST CELL FINAL EFFLUENT SUSPENDED SOLIDS OVER THE DURATION OF THE PROJECT

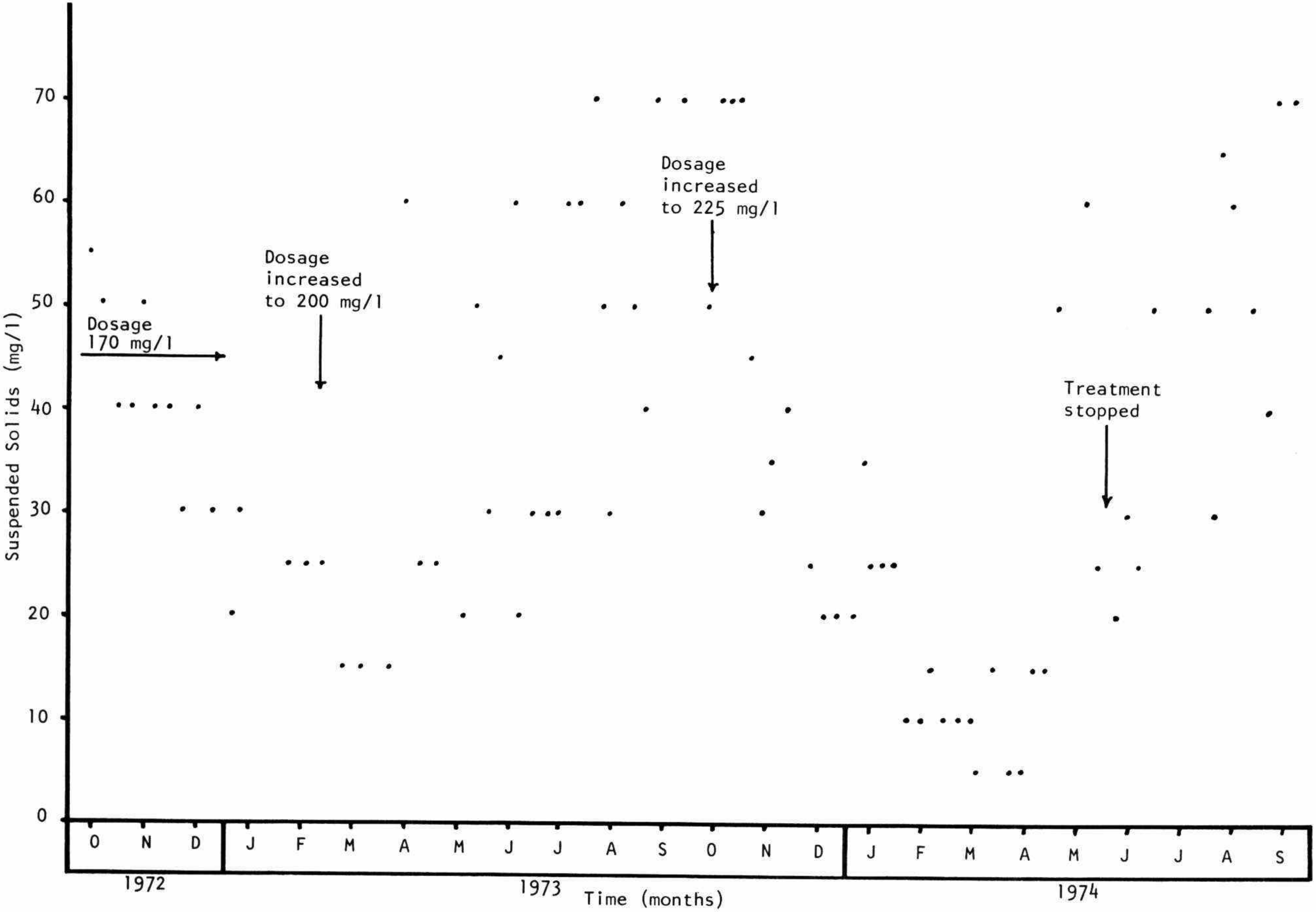

FIGURE 15. SHELBURNE - ALUM - WEST CELL FINAL EFFLUENT SUSPENDED SOLIDS OVER THE DURATION OF THE PROJECT

periods) after the chemical treatment was stopped the aluminum levels in the west lagoon remained above pretreatment levels at an average of 0.39 mg/l, while in the east lagoon after it was refilled, the aluminum levels were only 0.16 mg/l, again pointing out the residual effect of the chemical addition on the pond effluent.

The same phenomenon occurred with the sulphate. The average pretreatment value from the west lagoon was 67 mg/l; during the 200 mg/l alum dosage the average effluent values were 149 and 164 mg/l from the east and west lagoons, respectively; when the alum dosage was increased to 225 mg/l the average effluent sulphate levels were 163 and 171 mg/l in the east and west lagoons, respectively; in the four months after treatment stopped the level in the west lagoon remained above pretreatment levels at an average of 115 mg/l, while in the east lagoon when it was refilled the average effluent sulphate level was 83 mg/l.

Of the other parameters tested none showed a noticeable difference between the pre- and post-treatment samples. As with the Sutton data total and organic nitrogen concentrations and alkalinity levels in the raw sewage were compared with values in the "treated" sewage (Appendix B); there was essentially no difference in the total and organic nitrogen concentration, but there was a slight reduction in the alkalinity level in the "treated" sewage.

Two sediment depth surveys were conducted in 1974, one in February and the other in May, to find the rate of sediment accumulation using the methods outlined for Sutton. In both cells, the sediment heap was 100 - 150 ft (30 to 45 m) in diameter with a central depth of 30 - 36 in (75 - 90 cm). The central portion of the cone rapidly decreased in height to 10 in (25 cm) at a radius of 30 ft (9 m) from the influent pipe and then gradually decreased to the edge of the cone. The sediment depth in the rest of the lagoons was 2½ - 4 in (6 - 10 cm). In 1970 and 1971 the east and west cells, respectively, were drained and the sediment spread over the bottom of each cell. Even though the sediment in the east cell had one more year to accumulate, the amount of sediment in each heap was virtually the same with the methods used. As in the Sutton lagoon in the second survey three months later, there was no measurable change in the quantity or distribution of the sediment.

3.3 Mechanical Problems

With the alum feed system the only problem encountered was blockage of the chemical feed line due to crystallized alum. The problem did not occur frequently so the hoses and feed pumps were cleaned when necessary. A permanent answer would entail either diluting the alum with water or installing a sediment trap and filter on the chemical lines to the chemical pumps.

4 LIME - WATERFORD

4.1 Methods

4.1.1 Site description and chemical addition

Waterford, a town of approximately 2,000 people, is situated in the tobacco and fruit farming areas of Haldimand-Norfolk Region of Ontario. At the time that these experiments were carried out, the town was serviced by a one cell, 15 ac (6.1 ha) waste stabilization pond which discharged continuously to the upper reaches of Nanticoke Creek. The lagoon is located approximately 2,000 ft (600 m) from the last pumping station at the edge of town.

The lime feeding system was set up on the berm of the lagoon and used a temporary main to discharge the "treated" sewage to the lagoon. The location and the temporary discharge was chosen to avoid scaling in the permanent main.

The sampling program was identical to that noted above for Sutton and Shelburne.

The effluent flows out of the lagoons were measured with a V-notch weir. The levels flowing over the weir were recorded weekly. On the basis of these flows and the pond volume, the retention periods were estimated to be an average of 79 days and ranged from 64 days to 102 days.

A 3,000 gal (13,650 l) trailer-mounted slurry tank was set up approximately 10 ft (3 m) from the influent chamber at the lagoon. A building was constructed to enclose this tank, a sewage-lime mixing chamber and the equipment for the lime feeding system.

Raw sewage was diverted from the influent chamber to the trailer building via a 6 in (0.15 m) forcemain (Figure 16). A bypass back to the influent chamber was also installed. This 6 in (0.15 m) forcemain emptied into one end of a 500 gal (2,275 l) rectangular mixing tank. This tank was originally set up with mixers to mix the lime solution and the raw sewage, but it was soon found that the turbulence created by the incoming sewage was more than adequate for mixing.

The mixing tank had an 18 in (0.46 m) high baffle across the effluent end. The baffle had a 30° notch cut in it to provide travel for the activation of a float switch which activated the lime feed system.

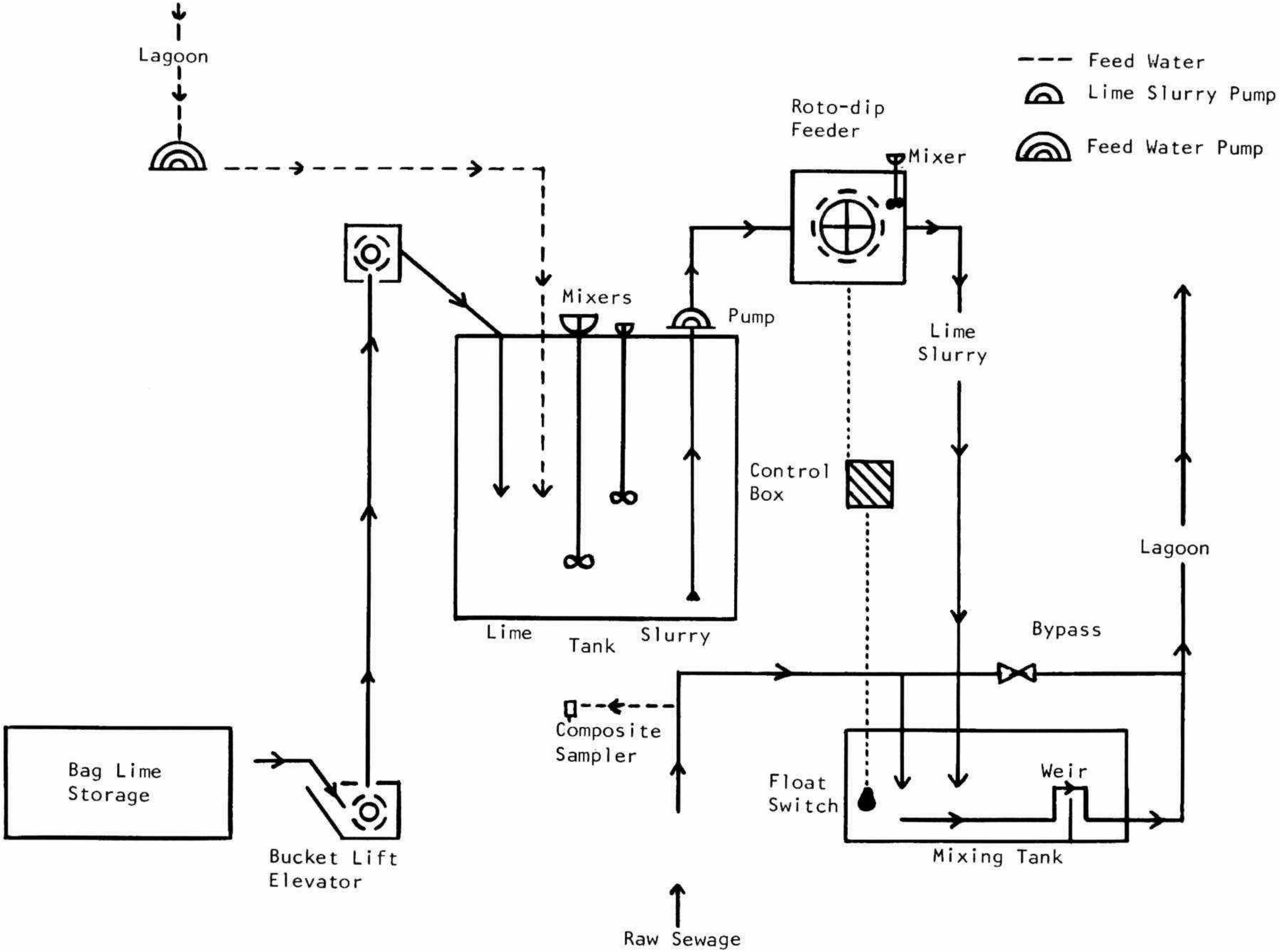

FIGURE 16. LIME FEED SYSTEM AT WATERFORD

A 10 in (0.3 m) temporary effluent pipe carried the treated raw sewage from the sewage-slurry tank approximately 100 ft (30 m) to the lagoon.

The bagged lime was stored on pallets outside the building. A bucket elevator delivered the dry lime to the slurry tank. "Lime treat", a polymer used for scale control, was added to the slurry at the rate of 10.75 ounces per ton (336 grams/metric ton) of dry lime. The lime slurry was pumped continuously into a "Roto-dip" chemical feeder with the excess returning to the slurry tank. When the float switch in the sewage-mixing tank indicated a flow in the sewage main, the "Roto-dip" was activated and delivered lime slurry into the stream of the inflowing sewage. Three mixers were used on the lime system, two in the slurry tank and one in the "Roto-dip" feeder.

Make-up water for the slurry was pumped from the lagoon during the ice-free period. Over the winter, water was brought in by a tank truck.

4.1.2 Jar tests and dosage

At Waterford a series of six jar tests was carried out over a period of three months prior to starting the treatment. As noted in Figure 17, the jar tests indicated that a dosage of 150 mg/l lime would be adequate for the reduction of total phosphorus concentration to below 1 mg/l. As with the preceeding projects the initial dosage of lime was based on the pump rated capacities which were checked against wet well level fluctuation before and after the intermittent pumping.

In response to effluent phosphorus levels above 1 mg/l, the dosage was adjusted upward three times over the duration of the project. These changes and their effective times are noted below:

Dosage of Lime in mg/l	Duration of Dosage
150	February 1973 - June 1973
175	June 1973 - September 1973
200	September 1973 - May 1974
400	May 1974 - November 1974

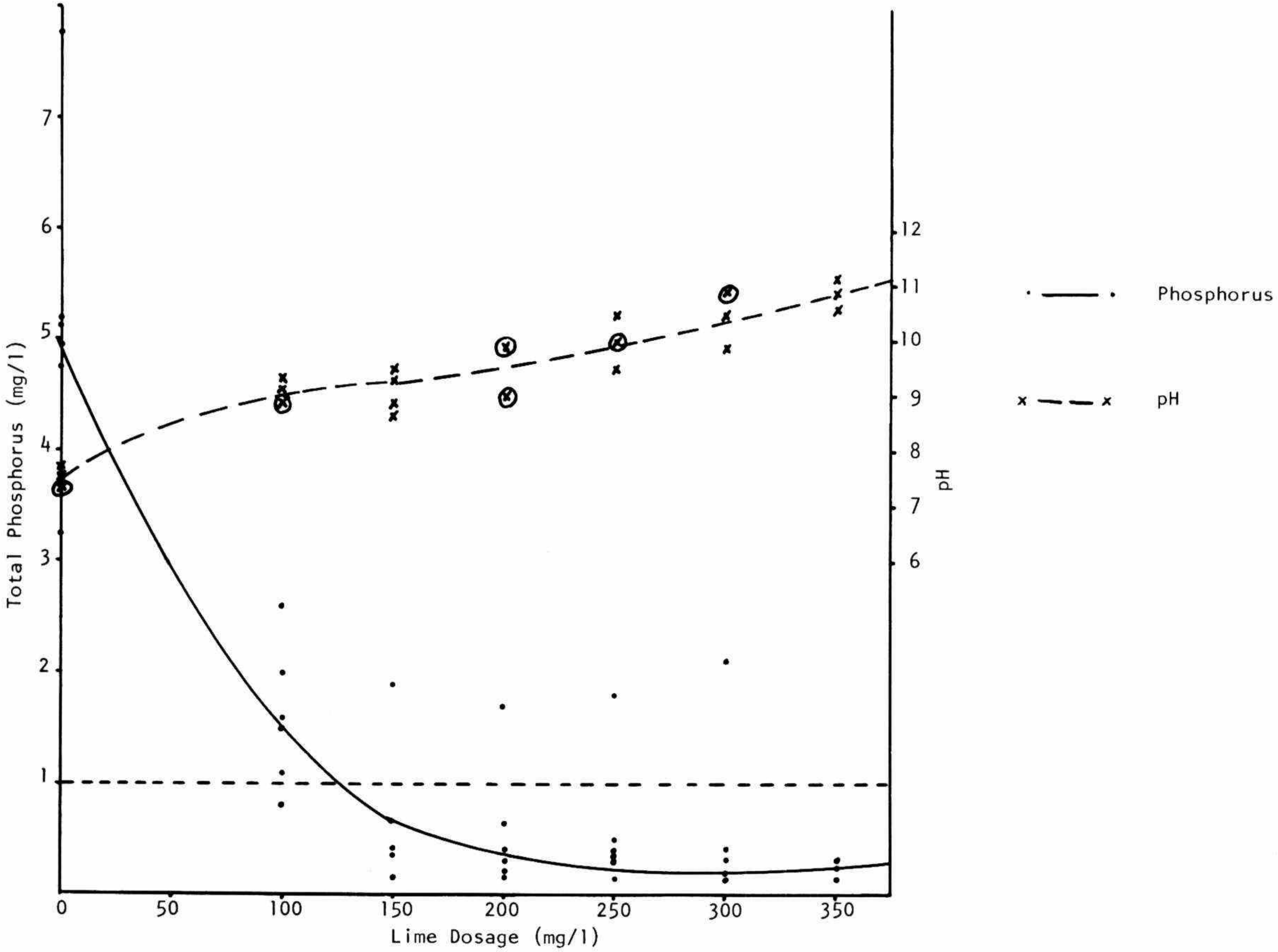

FIGURE 17. WATERFORD - LIME - JAR TEST RESULTS

4.2 Results and Discussion

Total phosphorus concentration in the raw sewage ranged from 1.6 to 6.9 mg/l over the duration of the project with the mean total phosphorus concentration lying between 4 and 5 mg/l (Figure 18).

It was found necessary to increase the dosage three times over the duration of the project, but as can be seen from Figure 18 these increases were not necessitated by any shifts in the raw sewage total phosphorus concentration. Also, no seasonal variation in the raw sewage phosphorus concentration was evident.

The effect of the lime treatment on the raw sewage total phosphorus concentration is presented in Figure C-1, Appendix C. As can be seen the lime treatment generally reduced the total phosphorus to less than 1 mg/l. In some cases the "treated" sewage total phosphorus was above 1 mg/l; this was probably due to the sampling method since this was a grab sample and thus subject to fluctuation in quality. The fluctuation in the total phosphorus concentration of the raw sewage (Figure 18), which was taken on a 24-hr composite basis, would tend to support this idea, and fluctuations encountered in grab samples could be of even greater magnitude.

Also, as can be seen in Figure 19, the "treated" total phosphorus levels exceeded 1 mg/l in substantially the same number of cases in a given time period at each of the dosages, which would suggest that the intermittent high "treated" total phosphorus levels were not a function of lime dosage. A similar phenomenon in the "treated" sewage phosphorus concentration occasionally exceeding 1 mg/l as it entered the lagoon was also evident at both Sutton and Shelburne.

The pretreatment final effluent had a total phosphorus concentration of 4.7 mg/l of which 3.9 mg/l was soluble (Figures 20 and 21). With the commencement of treatment in February, 1973 the total and soluble phosphorus concentrations declined gradually, reaching an initial low plateau in June, 1973 when the values were 1.7 and 1.2 mg/l, respectively. An increase in dosage in June, 1973 to 175 mg/l and a subsequent increase in September, 1973 to 200 mg/l failed to curtail a gradual increase in total and soluble phosphorus concentrations in the effluent, which peaked in November, 1973 at 3.0 and 1.5 mg/l, respectively. The pH level (Figure 22) exhibited a decrease

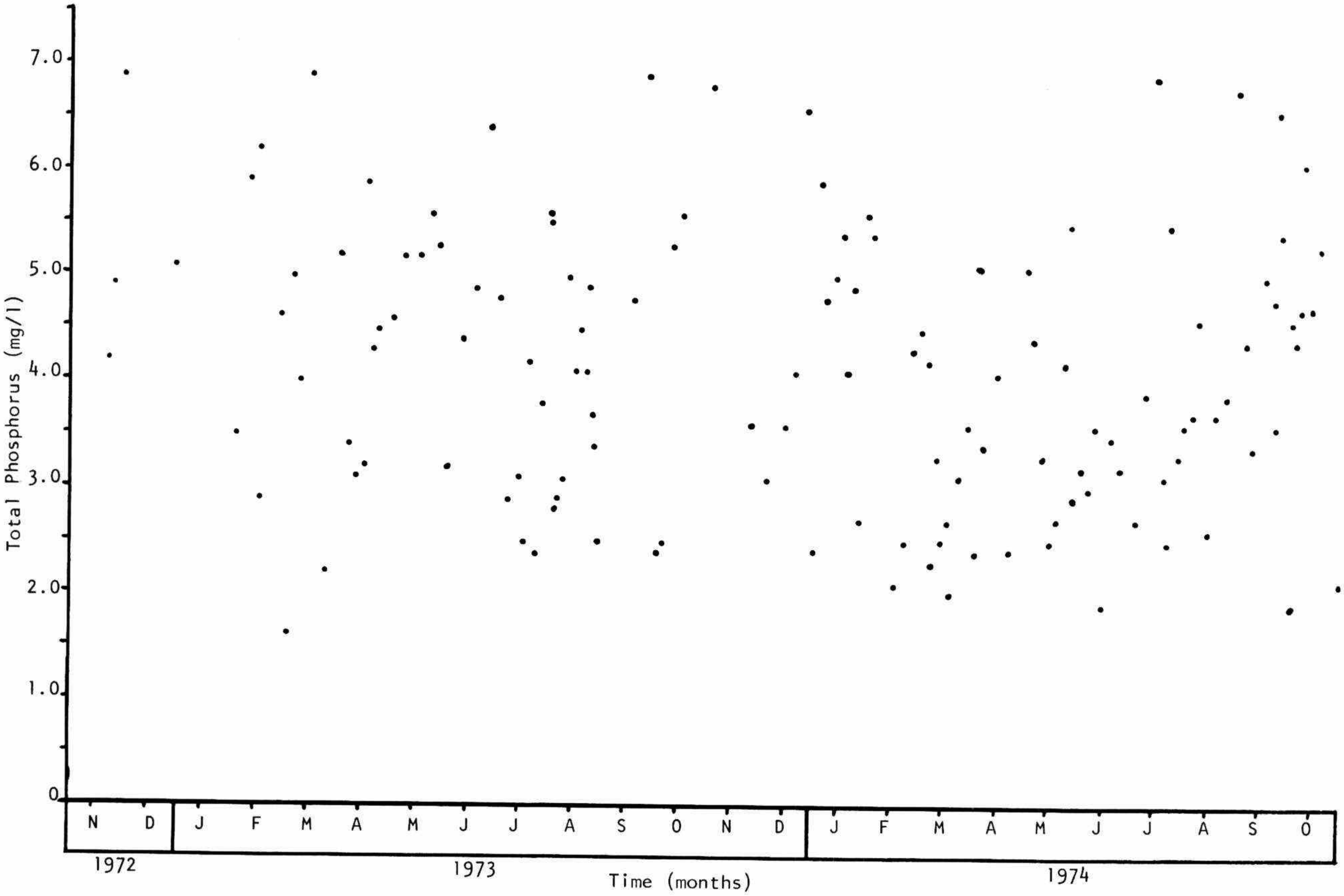

FIGURE 18. WATERFORD - LIME - RAW SEWAGE TOTAL PHOSPHORUS OVER THE DURATION OF THE PROJECT

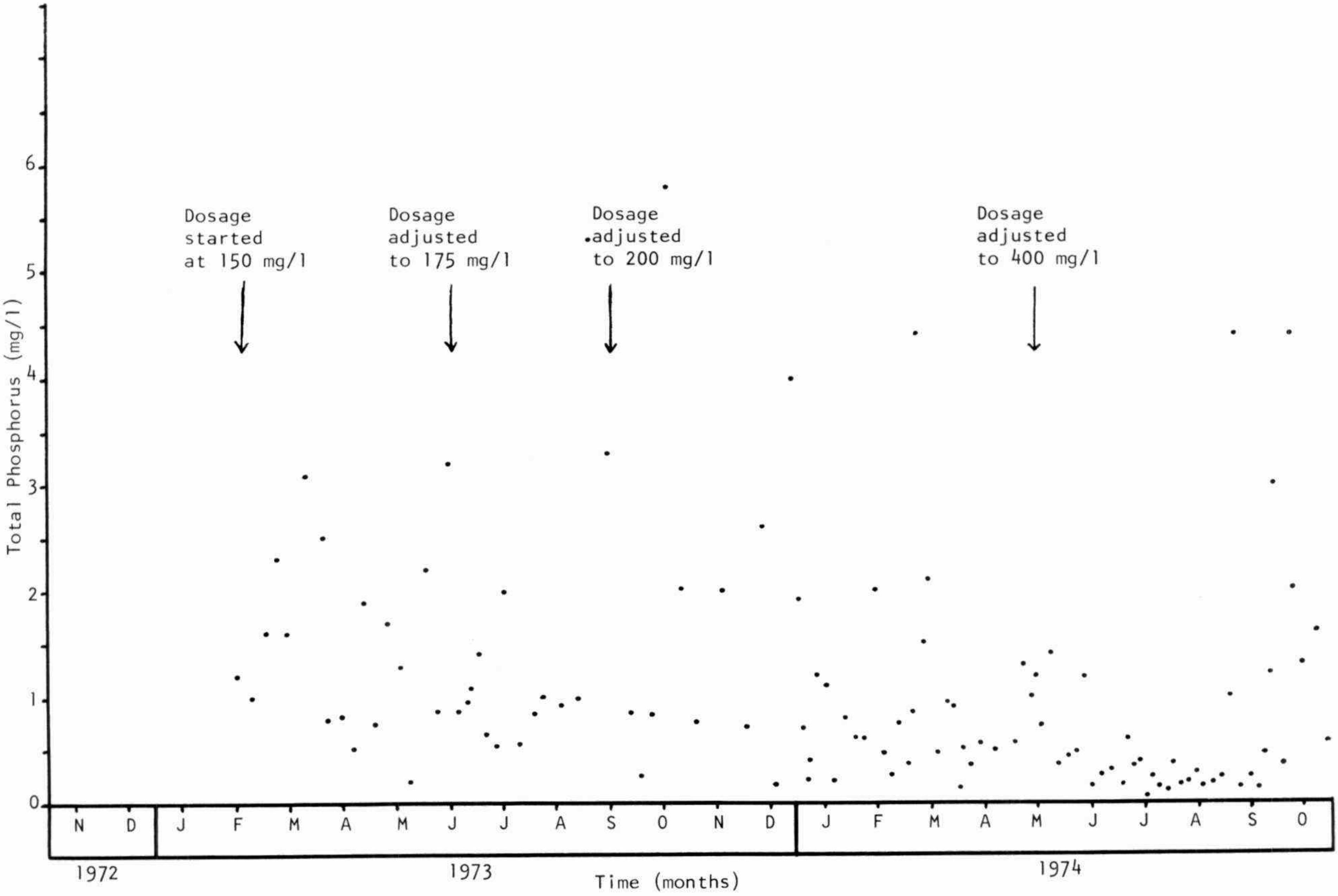

FIGURE 19. WATERFORD - LIME - TOTAL PHOSPHORUS CONCENTRATION IN THE "TREATED" SEWAGE OVER THE DURATION OF THE PROJECT

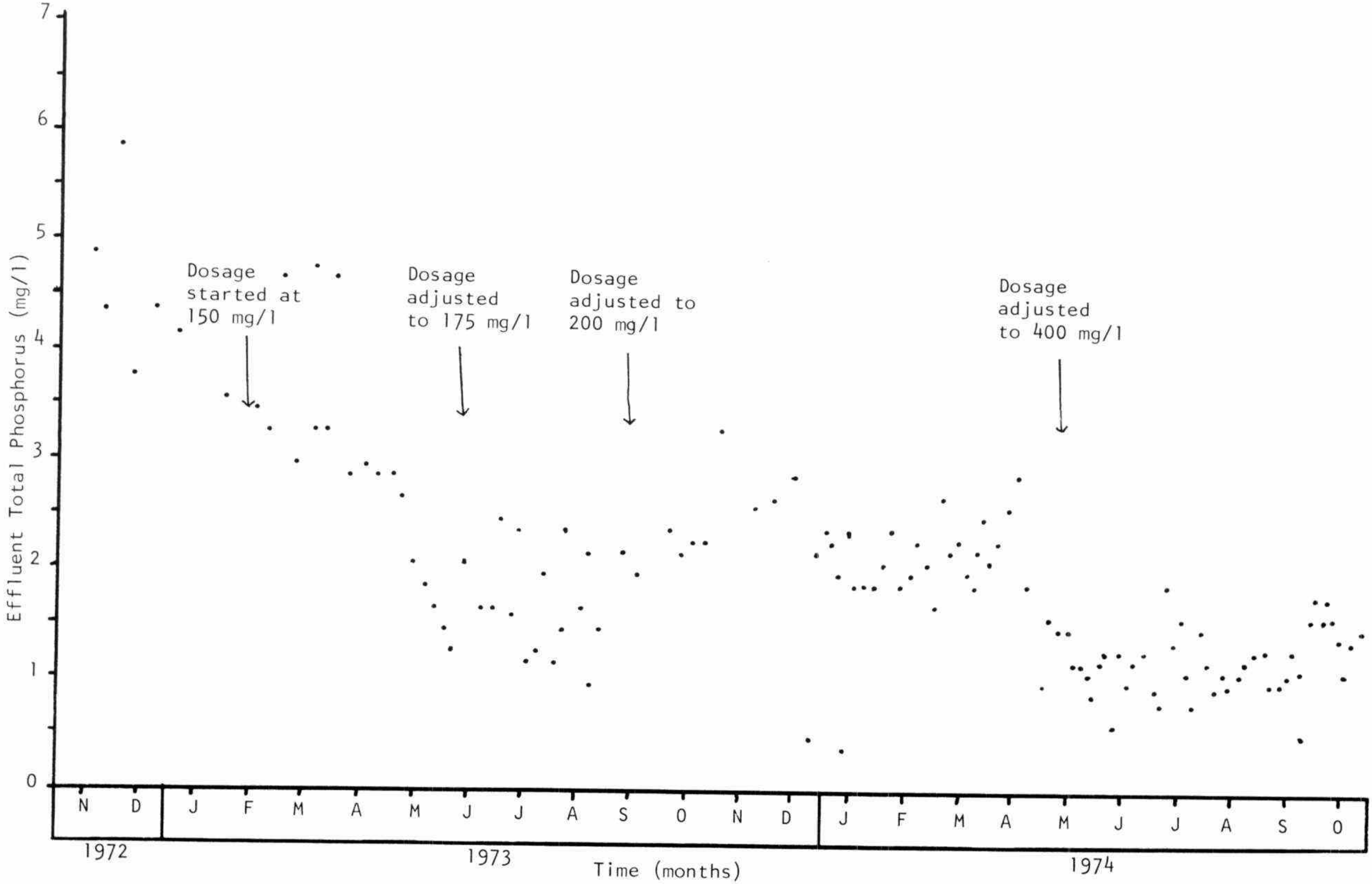

FIGURE 20. WATERFORD - LIME - EFFLUENT TOTAL PHOSPHORUS OVER THE DURATION OF THE PROJECT

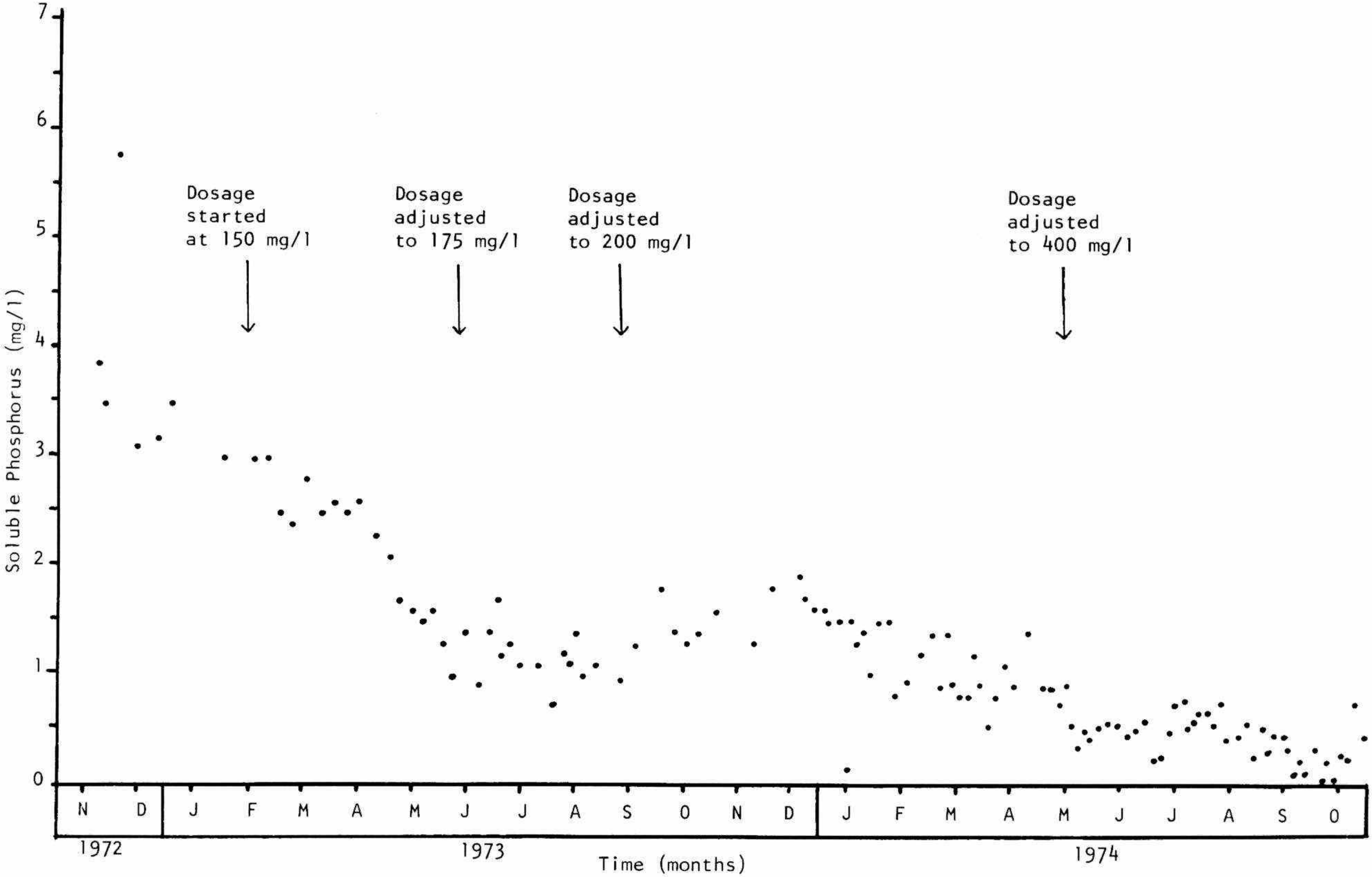

FIGURE 21. WATERFORD - LIME - EFFLUENT SOLUBLE PHOSPHORUS OVER THE DURATION OF THE PROJECT

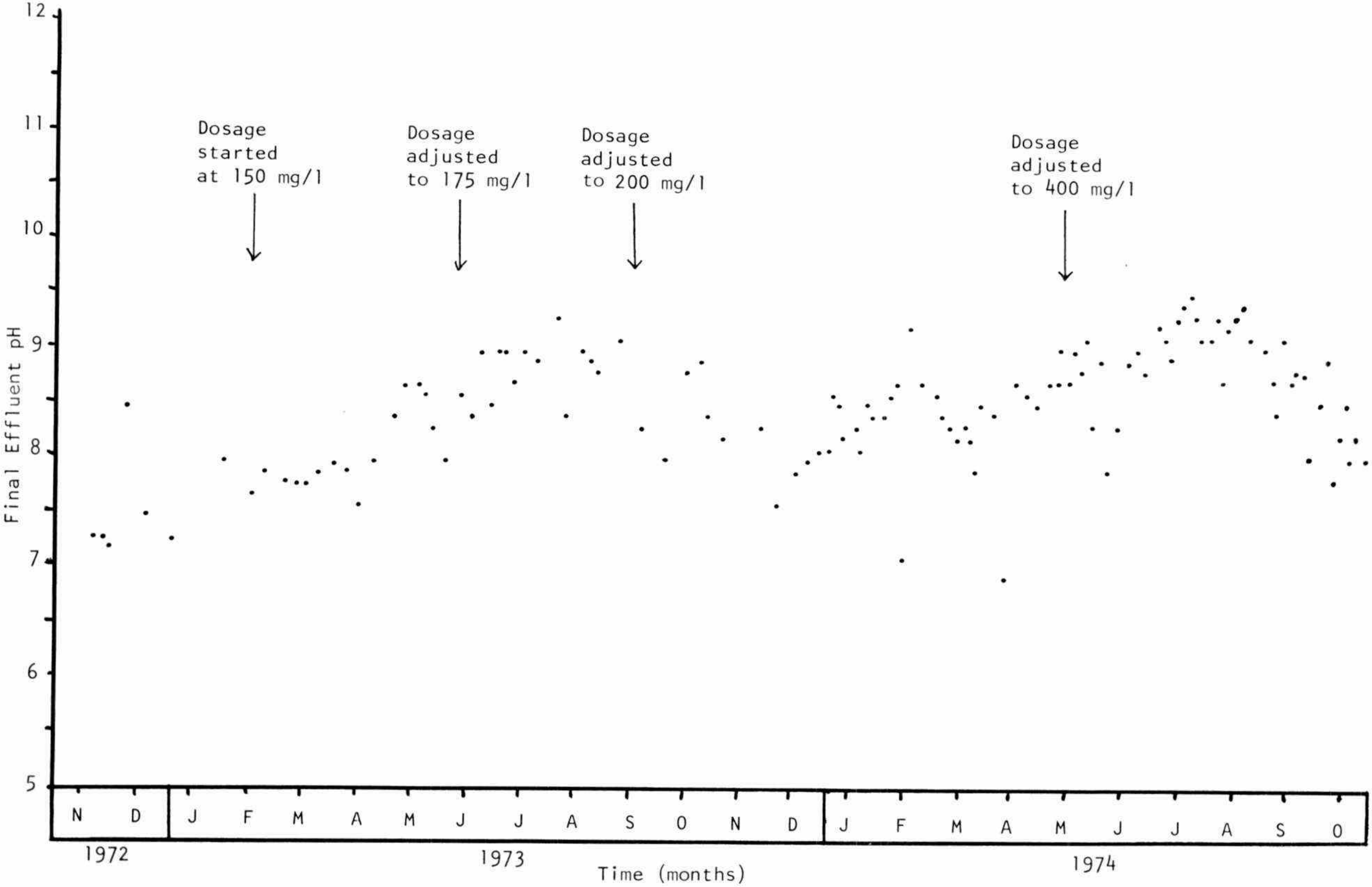

FIGURE 22. WATERFORD - LIME - FINAL EFFLUENT pH LEVELS OVER THE DURATION OF THE PROJECT

during this period. The effluent phosphorus in the lagoon remained relatively stable over the winter months with the total and soluble levels at approximately 2.0 and 1.0 mg/l, respectively. In May, 1974 a drop in effluent phosphorus levels occurred bringing the total and soluble phosphorus levels to 1.3 and 0.5 mg/l, respectively. The dosage rate was changed to 400 mg/l in early May, but with an average 78-day retention time this should not have changed the phosphorus concentration in the effluent until mid-July. The total phosphorus levels in the effluent remained relatively stable at just above 1 mg/l until October when the concentration increased to 1.5 mg/l, and then to 1.7 mg/l in November. The increase in total phosphorus in October was not accompanied by a similar increase in soluble phosphorus, although the November samplings exhibited similar increases in both soluble and total phosphorus.

Seasonal trends are difficult to assess over such a short period. From the limited information available, the phosphorus concentration increased in the late fall, maintained this level over the winter and decreased in the spring. This is directly opposed to what occurred at Sutton and Shelburne, where the total phosphorus level decreased in the fall, remained low over the winter and increased again in the spring. The lagoon effluent total phosphorus concentration at Waterford remained relatively stable over the ice-covered period in 1973-74. A decrease in soluble phosphorus concentration was observed over this same ice-covered period. The two summer seasons exhibited effluent phosphorus levels generally lower than those encountered in the remainder of the year.

The response of phosphorus levels in the "treated" influent and lagoon effluent to lime dosage changes are outlined in Table 1. A number of points are evident from this table.

1) As the dosage of lime is increased, the phosphorus concentration in the "treated" samples decreased.
2) The effluent total phosphorus concentration did not reflect the lower concentrations in the "treated" influent until after the dosage had been raised to 400 mg/l lime.
3) The effluent soluble phosphorus concentrations reflected the decrease in the "treated" influent soluble phosphorus concentrations. The largest decrease in effluent soluble phosphorus

TABLE 1. RESPONSE OF PHOSPHORUS LEVELS TO DOSAGE CHANGES IN LIME TREATMENT AT WATERFORD

Dosage mg/l lime	Total Phosphorus in mg/l			Soluble Phosphorus in mg/l		
	"Treated" Influent*	Final Effluent**	Increase	"Treated" Influent*	Final Effluent**	Increase
150	1.3	2.0	0.7	0.6	1.5	0.9
175	1.1	2.1	1.0	0.4	1.3	0.9
200	0.9	2.0	1.1	0.2	1.1	0.9
400	0.5	1.4	0.9	0.1	0.4	0.3

* mean "treated" influent phosphorus level over the duration that the dosage was used.

** time periods for the mean effluent phosphorus concentration beginning 90 days after the commencement of the dosage and ending 30 days after the dosage had been readjusted thus taking into account the average 78 day retention time and avoiding the transition period.

concentration was noted after the dosage had been increased to 400 mg/l.

4) The largest portion of the increase in total phosphorus concentration during the time in the lagoon was due to the increase in the soluble phosphorus concentration for the first three dosages used, which would suggest that the increases were due to a resolubilization of the phosphorus in the lagoon rather than any resuspension of the precipitated material. The pH level in the effluent, generally below 9.5 (Figure 22), would support this theory. At the highest dosage of 400 mg/l lime, only 33% of the increase in total phosphorus is attributed to resolubilization of phosphorus.

In Figure 23 the average effluent BOD of 35 mg/l prior to lime addition was not significantly changed after the commencement of lime treatment. The limited pretreatment samples are in the same range as the average effluent BOD level of 31 mg/l observed by the MOE Project Operations Section over the five years prior to treatment.

In terms of the treatment process effect on BOD, an examination of Figure C-2, Appendix C, points out that many points are above the diagonal-equal line, showing that the BOD was reduced in many of the cases. The amount of BOD removal is shown to vary widely.

Figure 24 points out the variation in raw sewage BOD levels at the Waterford lagoon. A canning factory with intermittent high organic waste discharges may account for the high and erratic raw sewage BOD levels.

Figure C-3, Appendix C, depicts the suspended solids levels in the raw and "treated" samples at Waterford. It is logical to expect a substantial reduction in the concentration of solids after chemical addition, and this is shown to be the case with the majority of the points near the vertical axis above the diagonal-equal line.

The suspended solids levels in the "treated" samples of approximately 49 mg/l were essentially maintained over the retention time in the lagoon with the effluent averaging 54 mg/l suspended solids (Figure 25). It must be pointed out that this is essentially the same level as observed in the lagoon effluent just prior to treatment, and hence the net effect of

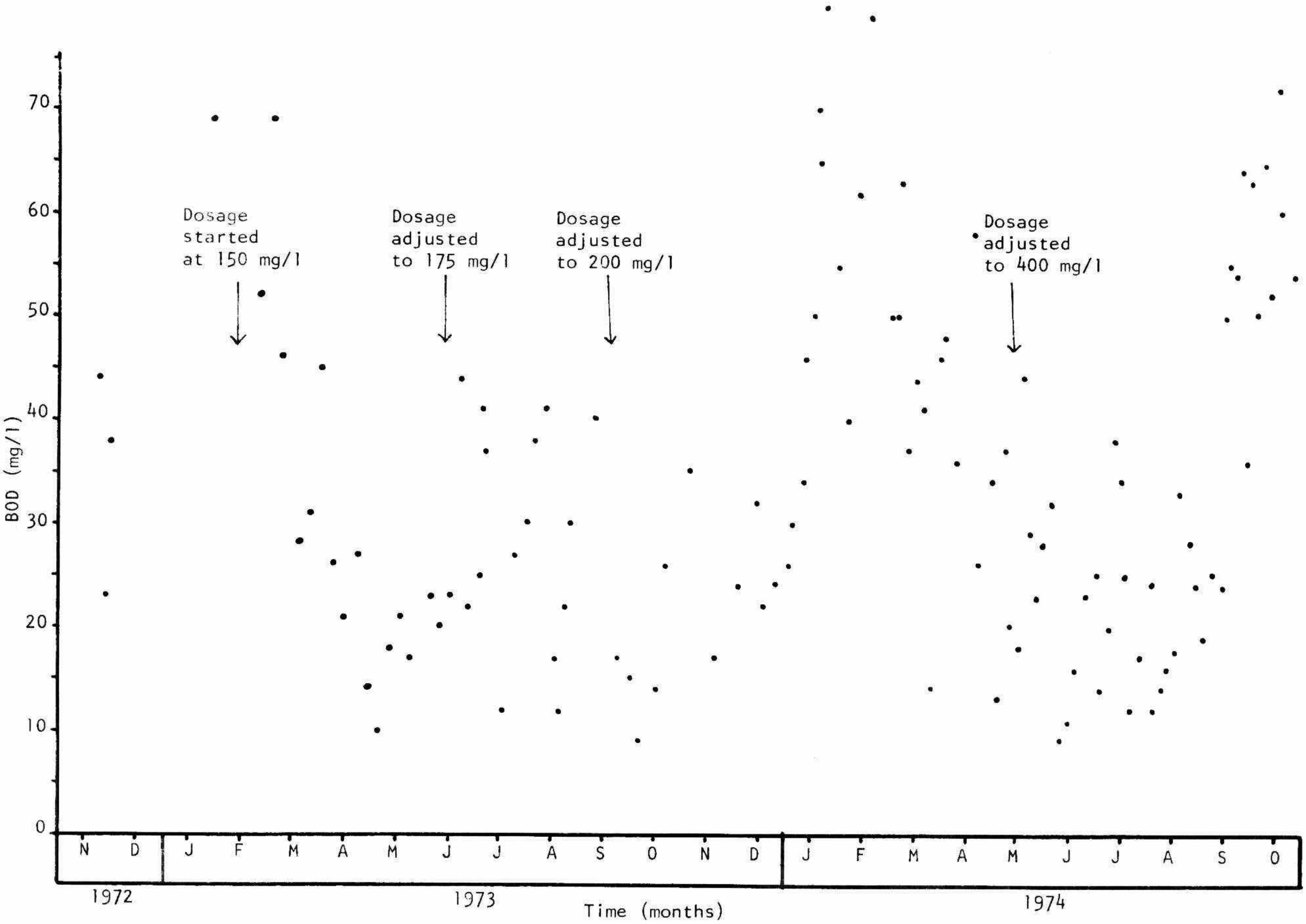

FIGURE 23. WATERFORD - LIME - EFFLUENT BOD LEVELS OVER THE DURATION OF THE PROJECT

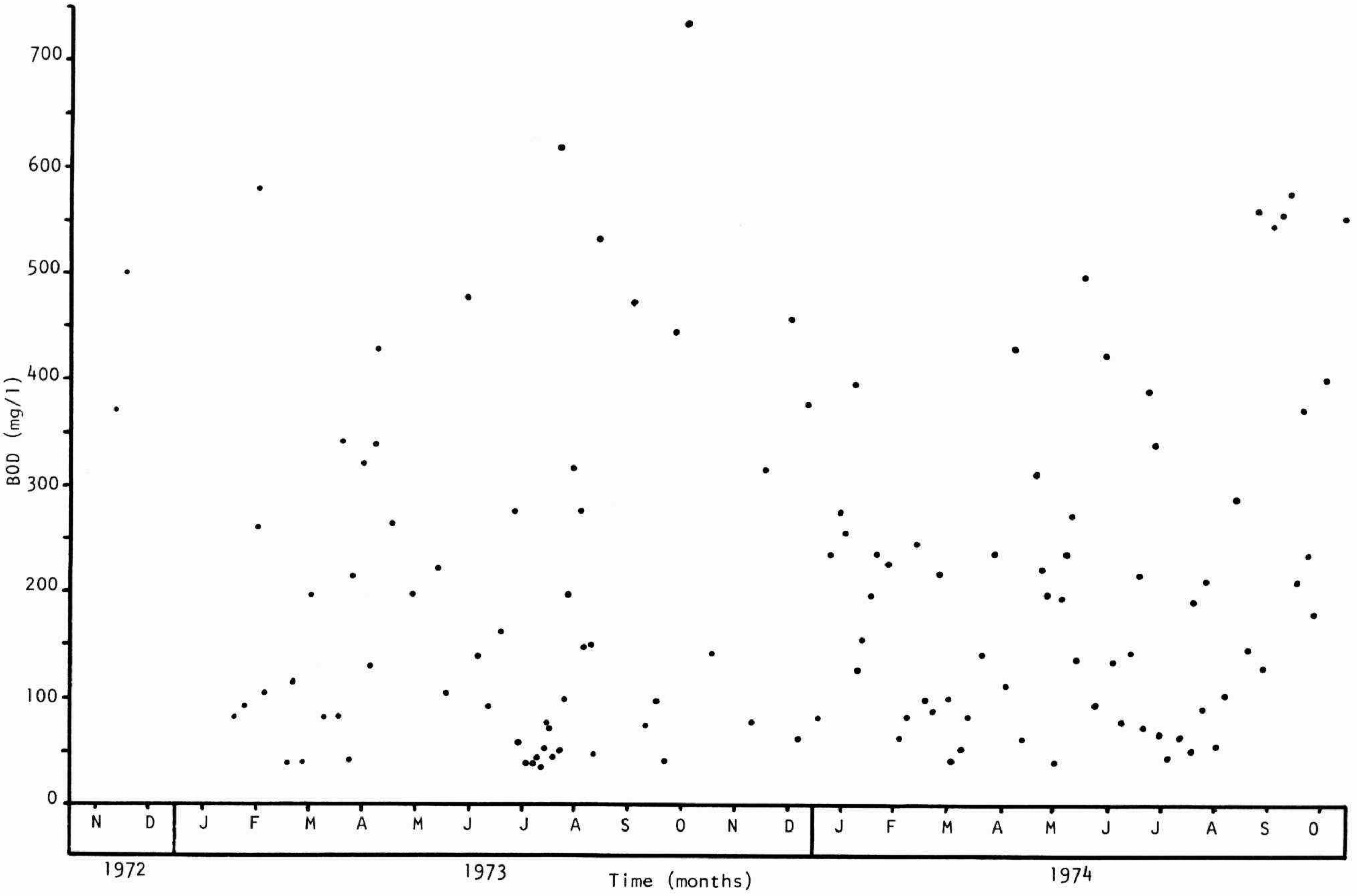

FIGURE 24. WATERFORD - LIME - RAW SEWAGE BOD CONCENTRATIONS OVER THE DURATION OF THE PROJECT

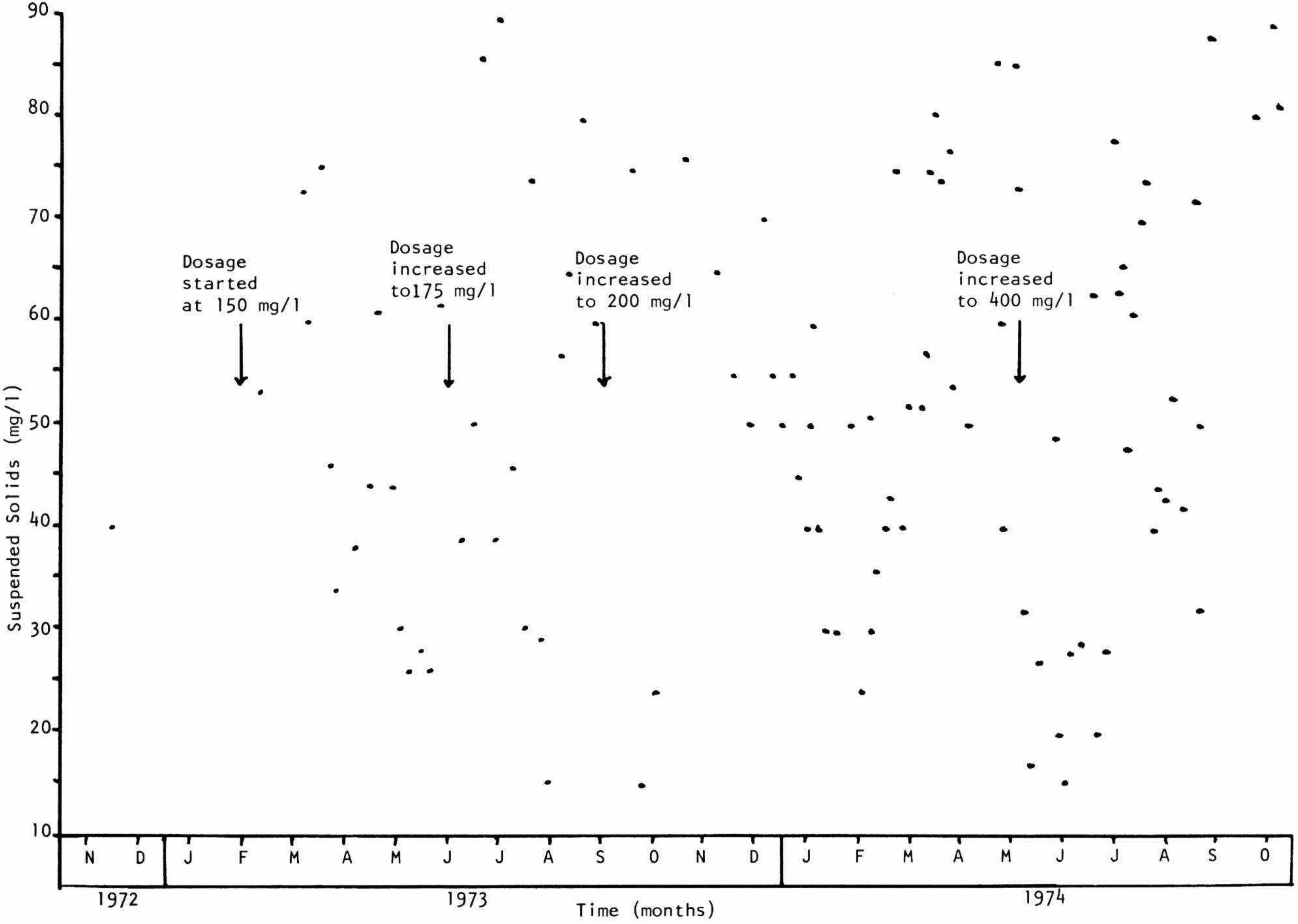

FIGURE 25. WATERFORD - LIME - FINAL EFFLUENT SUSPENDED SOLIDS OVER THE DURATION OF THE PROJECT

the treatment on suspended solids over the entire system was virtually undetectable. The MOE Operating Summaries show the average suspended solids over the five years prior to treatment to be 39 mg/l, which would reinforce this hypothesis.

As shown in Figure C-4, Appendix C, the addition of the lime raised the mean raw sewage pH of 7 to approximately 10 in the "treated" sewage. The mean final effluent pH of 8.6 shows a considerable drop in pH over the retention time in the lagoon. Although the seasonal variations and dosage changes tend to mask one another (Figure 22), there was a high effluent pH in the summer during the period of high biological activity in the lagoon, followed by a decline in the fall, and then a gradual increase over the winter and spring to the summer peak. The lowest pH in the fall coincided with the highest effluent phosphorus levels.

As can be seen in Figure C-5, Appendix C, the lime addition had little or no effect on total nitrogen. A decrease in organic nitrogen concentrations would have been expected due to the decrease in suspended solids but this is not evident from the limited number of samples (see Figure C-6, Appendix C).

The total alkalinity of the raw sewage was approximately 250 mg/l over the duration of the project. There was considerable variation in the "treated" sample alkalinity. However, a decrease of 50 to 100 mg/l alkalinity was generally noted from the raw sewage to the "treated" sewage. The residual alkalinity in the "treated" sample was probably due to factors other than bicarbonate ion as the pH in the "treated" sample was generally above 10 after the dosage was increased to 175 mg/l lime. The alkalinity in the final effluent was generally at or above the levels encountered in the raw sewage. This increase in alkalinity during the retention time in the lagoon corresponded with a decrease in pH levels to below 9.5.

A phenomenon similar to that observed for alkalinity also occurred with hardness, magnesium, calcium and iron in which an initial decrease was noted after treatment with lime, followed by a return to approximately raw sewage concentrations in the final effluent.

Samples for bacterial analysis were collected on a monthly basis from the raw sewage, "treated" sewage and in final lagoon effluent. The mean results are presented in Table 2.

As shown in Table 2, the high initial number of organisms in both the fecal and total coliform bacteria types was substantially reduced in the "treated" sewage. An increase of one and three orders of magnitude for the fecal and total coliform averages, respectively, is noted between the "treated" sample and the final effluent sample.

TABLE 2. MEAN BACTERIOLOGICAL RESULTS AT WATERFORD

Sample	Mean Fecal Coliforms per 100 ml	Mean Total Coliforms per 100 ml
Raw Sewage	5.1×10^6	1.3×10^8
"Treated" Sewage	1.7×10^2	4.2×10^2
Final Lagoon Effluent	8.5×10^3	1.5×10^5

At Waterford, the influent location in the lagoon was changed, and thus an estimation of the volume of the new sludge mound was made. The upper surface of the sediment was obtained with a "portable sludge level detector", while the pond bottom was determined by pushing a 5 inch (13 cm) disk on the end of a pole, as far down as possible. The difference was assumed to be the sediment thickness. Over the first year of operation approximately 1,300 cu ft of sludge accumulated, extending in a radius 30 ft around the influent. Measurements of sludge depth at other locations in the lagoon did not show appreciable change over this same time period.

4.3 Mechanical Problems

The lime handling system as used in Waterford was not the optimum available on the market but was set up as such due to economic considerations and the temporary nature of the project. Nevertheless, for the purpose of future applications it is important to note the mechanical problems that were specific to this system as well as those that would be generally encountered in any lime feeding system for the purpose of continual chemical addition to a lagoon.

At Waterford, the most troublesome problem in the system was the material handling of the lime prior to feeding. The slurry had to be mixed continuously and thus checks had to be made daily on the system. The lime treatment method as set up in Waterford was labour intensive requiring daily maintenance plus manual loading of the lime into the bucket elevator at intervals ranging from three to six days.

Dust control problems were encountered during the loading of the dry lime into the slurry tank.

An accumulation of grit particles occurred on the bottom of the lime slurry tank which necessitated cleaning at frequent intervals.

Due to the nature of the slurry, continuous pumping was necessary with the excess being pumped back into the slurry tank. The abrasive nature of the slurry caused the pump parts to fail frequently causing interruptions in the treatment.

Scaling of the discharge line from the treatment trailer to the lagoon presented a problem. Mechanical cleaning had to be carried out frequently. Finally, clean-outs at the bends were installed and manual descaling at these points on a regular basis alleviated the problem.

5 DESIGN CONSIDERATIONS

5.1 Alum and Ferric Chloride

Although the experiments were set up in a temporary fashion a number of important design considerations came to light.

1) The position of chemical addition is quite flexible and can be anywhere in the main after the sewage pumps to the edge of the lagoon, as long as there is a sufficient length of pipe to provide mixing of the chemical with the sewage. The operation of the chemical feed pump must be connected in some fashion to the flow of sewage in the main. A pressure switch might be used but the most reliable method found was to connect the feed pump, through an electrical relay, to the sewage pumps so that the chemical feed is activated when either sewage pump is operating. When the point of addition is in the main after the sewage pumps the dosage is applied uniformly to all the sewage going to the lagoon.

2) It is recommended that back pressure valves be installed on the chemical feed lines to prevent any momentary overdose due to syphoning or negative pressure.

3) In case of accidental leakage of the chemical from the storage tank, feed pump or connecting hosing a retaining wall should surround these facilities. This was not done at Sutton and there were two occasions when chemical leakage caused extensive damage to the grass in the park where the chemical storage facilities were located.

4) It was a problem to arrive at an accurate dosage since it was difficult to determine the sewage pump output. At Sutton the sewage pumps were rated at 700 Igpm (3,180 l/m) by the manufacturer; the Technical Services Branch of this Ministry estimated the pump output at 600 Igpm (2,730 l/m); from the height of liquid flowing over the influent weir the measured pump output was 500 Igpm (2,275 l/m); and if the amount flowing into the lagoon equals the amount flowing

out, on a yearly basis, the pump output was estimated at 450 Igpm (2,098 l/m).

However, for the purposes of phosphorus removal, the sewage pump output is only important initially when estimating the correct dosage from the jar test results. As shown above, if the estimate is grossly in error, it can lead to a drastic over or under dose being applied. After one or two retention periods of operation the chemical feed pump output can be adjusted either up or down depending on the total phosphorus in the final effluent from the lagoon.

5.2 Lime

Although the results of this study do not permit recommending the use of this chemical under the conditions tested, certain design considerations are pertinent to future applications.

1) A lime treatment facility must be located as close as possible to the lagoon due to scaling problems in the discharge line. A water supply and electrical service are required for the treatment facility at the lagoons.

2) The effluent line from the lime addition point should be as straight as possible to avoid scale build-up due to turbulence at the bends. This effluent line should be easily accessible for cleaning and descaling. The "usual" gravity flow underground system from a distribution box to the centre of the lagoon should not be used with a lime feeding system.

3) A mechanical system incorporating pneumatic handling of bulk lime would reduce the labour input considerably.

4) The "package plant" lime feed system would be readily adaptable to this type of application. This system would incorporate a silo storage unit, volumetric feeder and a slurry tank.

5) Specific details regarding the handling of lime are available in the book "Lime Handling, Application and Storage in Treatment Processes" (National Lime Association, 1971).

REFERENCES

Canada/United States International Agreement on Great Lakes Quality, April, 1972.

Ehlert, N.G., 1972. "The effects of influent alum injection on the effluent from continuous discharge lagoons", Ontario Ministry of the Environment, Research Branch, Publication No. W35.

Graham, H.J. and Hunsinger, R.B., 1974. "Phosphorus removal in seasonal retention lagoons by batch chemical precipitation", COA Project No. 71-1-13, Research Report No. 13.

National Lime Association, 1971, "Lime, Handling, Application and Storage in Treatment Processes", Bulletin 213, Washington, D.C., U.S.A.

Operation Summaries, Water Pollution Control Projects, 1968-1972, Technical Services Branch, Ontario Ministry of the Environment.

Sawyer, C.N., 1947. "Fertilization of lakes by agriculture and urban drainage", Jour. New England Water Works Assoc., 61 (2):109-127. IN: Mackenthun, K.M., 1965. "Nitrogen and Phosphorus in Water", U.S. Dept. of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical assistance of the following individuals: J.P. Stogre, S. Carrol, J. Barron, B. Bradley and S. Dunnets. The cooperation and assistance of the staff members of the towns of Sutton, Shelburne and Waterford were appreciated.

APPENDIX A

SUTTON - FERRIC CHLORIDE

APPENDIX A

SUTTON - FERRIC CHLORIDE

As noted in the methods section, the "treated" sewage sample is an estimation of the initial effect of the chemical addition on the raw sewage after it enters the lagoon. This sample was obtained by taking a sample of the chemically treated raw sewage just before it entered the lagoon and allowing it to settle for one hour, then sampling the supernatant.

In the following appendices, the raw sewage data are on the vertical axis and the "treated" sewage data on the horizontal axis. A diagonal line of 45^{o} from the origin is where the two samples would have equal concentrations of the parameter being examined. A shift of the points on the graph towards the vertical axis, above the diagonal-equal line, denotes a reduction in the concentration of the parameter due to the chemical addition and settling, while a shift of the points towards the horizontal axis, below the diagonal-equal line, denotes an increase in the concentration of the parameter.

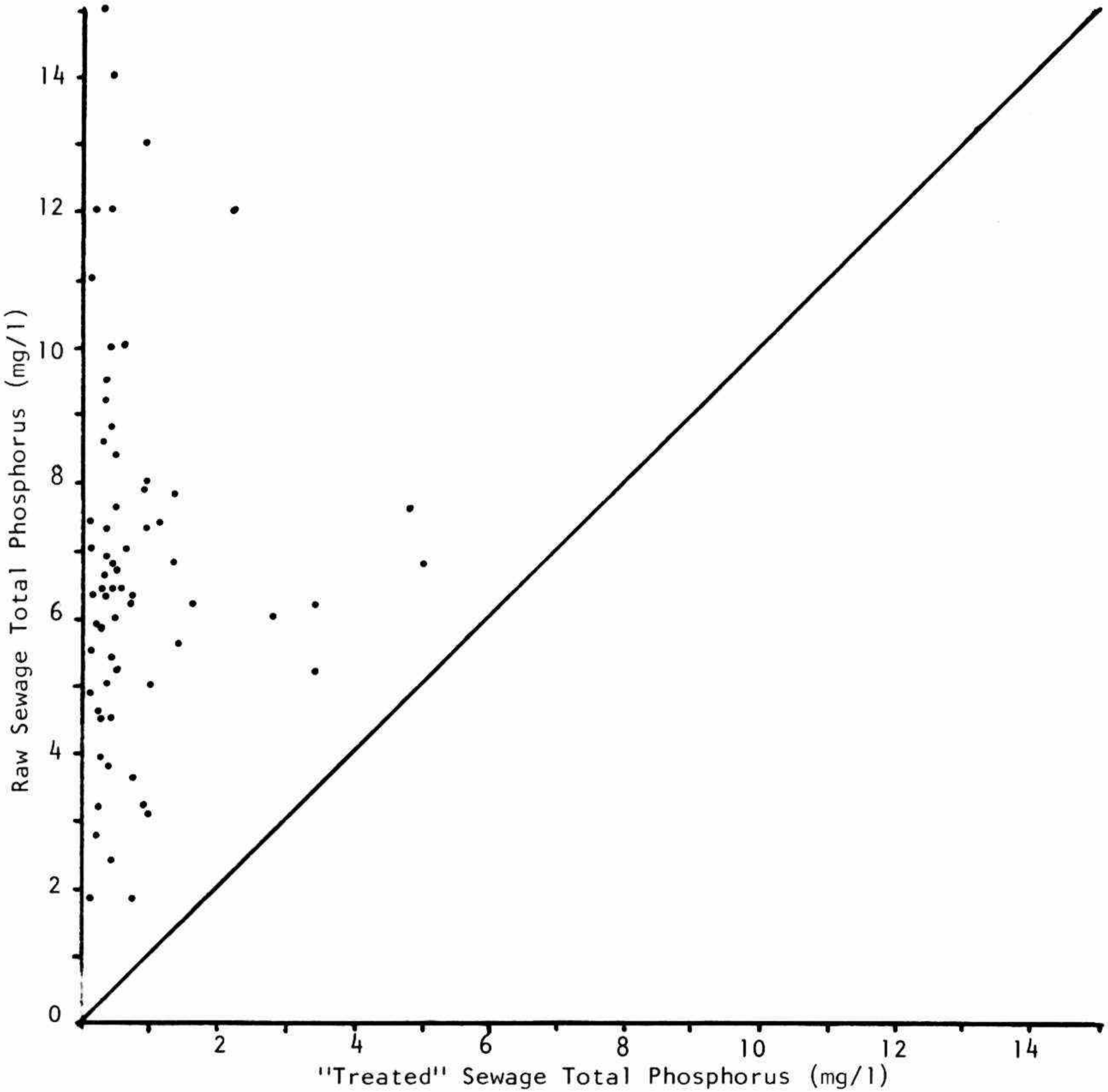

FIGURE A-1. SUTTON - FERRIC CHLORIDE - A COMPARISON OF TOTAL PHOSPHORUS IN THE RAW AND "TREATED" SEWAGE

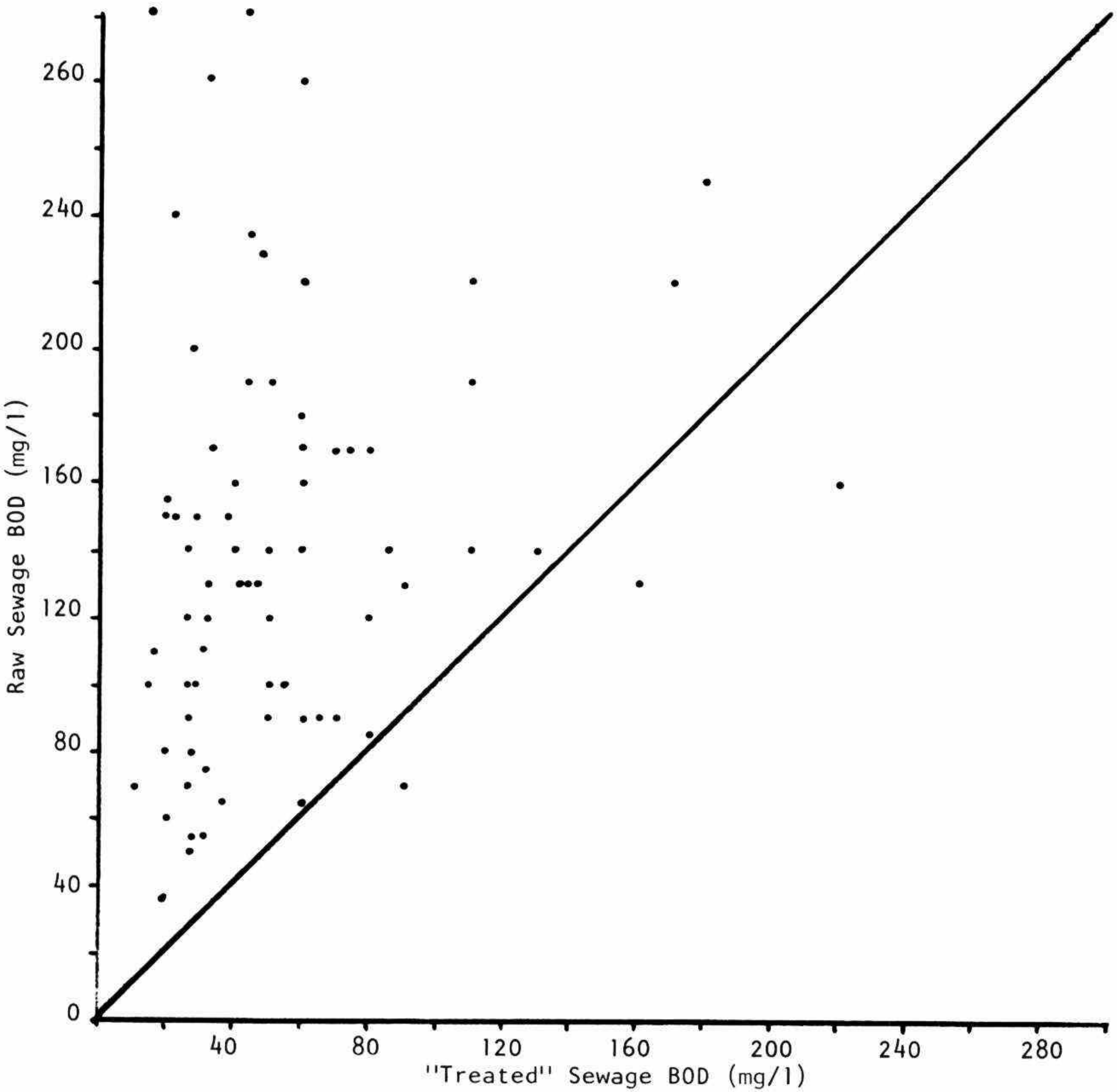

FIGURE A-2. SUTTON - FERRIC CHLORIDE - A COMPARISON OF BOD IN RAW AND "TREATED" SEWAGE

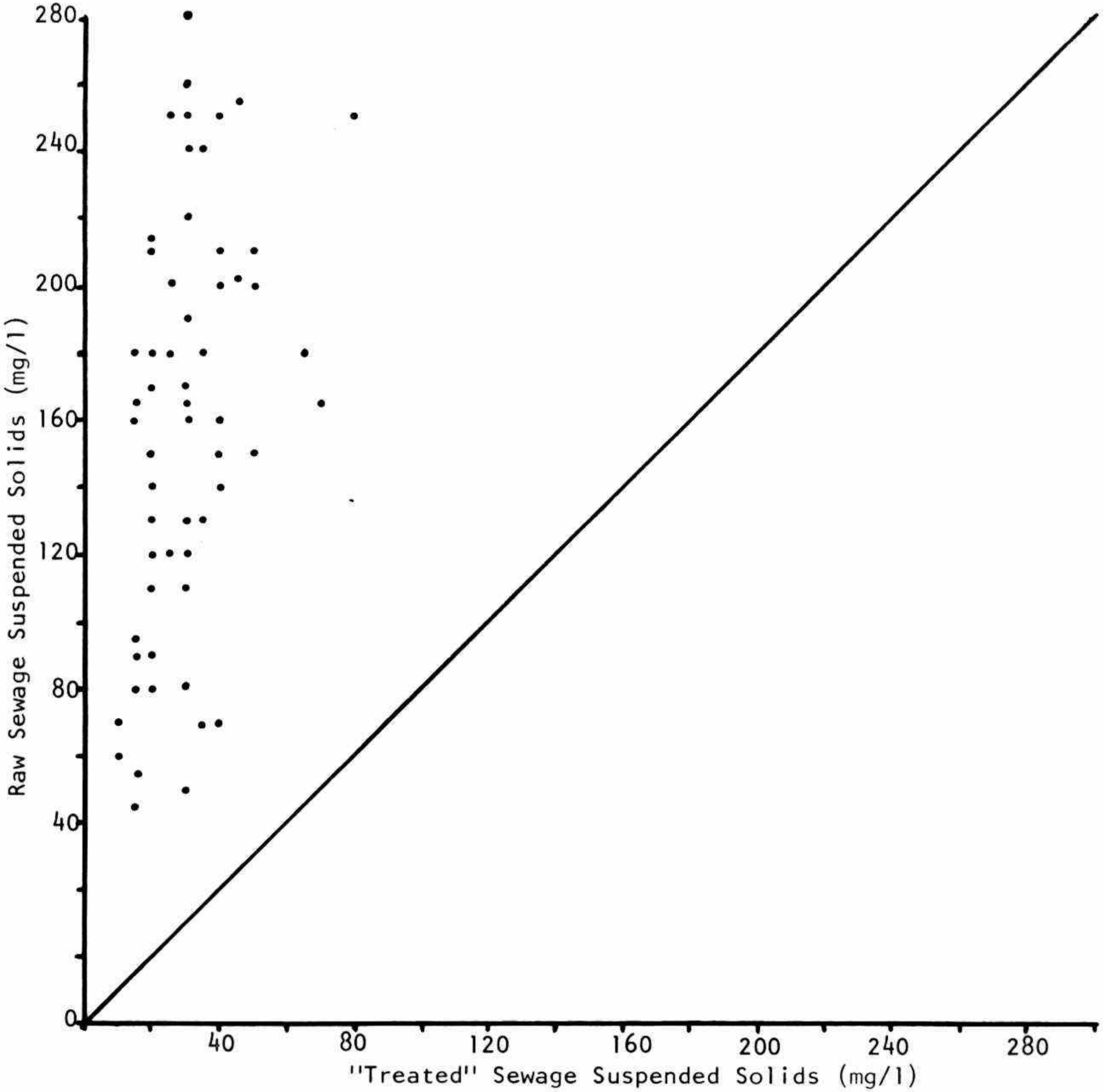

FIGURE A-3. SUTTON - FERRIC CHLORIDE - A COMPARISON OF SUSPENDED SOLIDS IN THE RAW AND "TREATED" SEWAGE

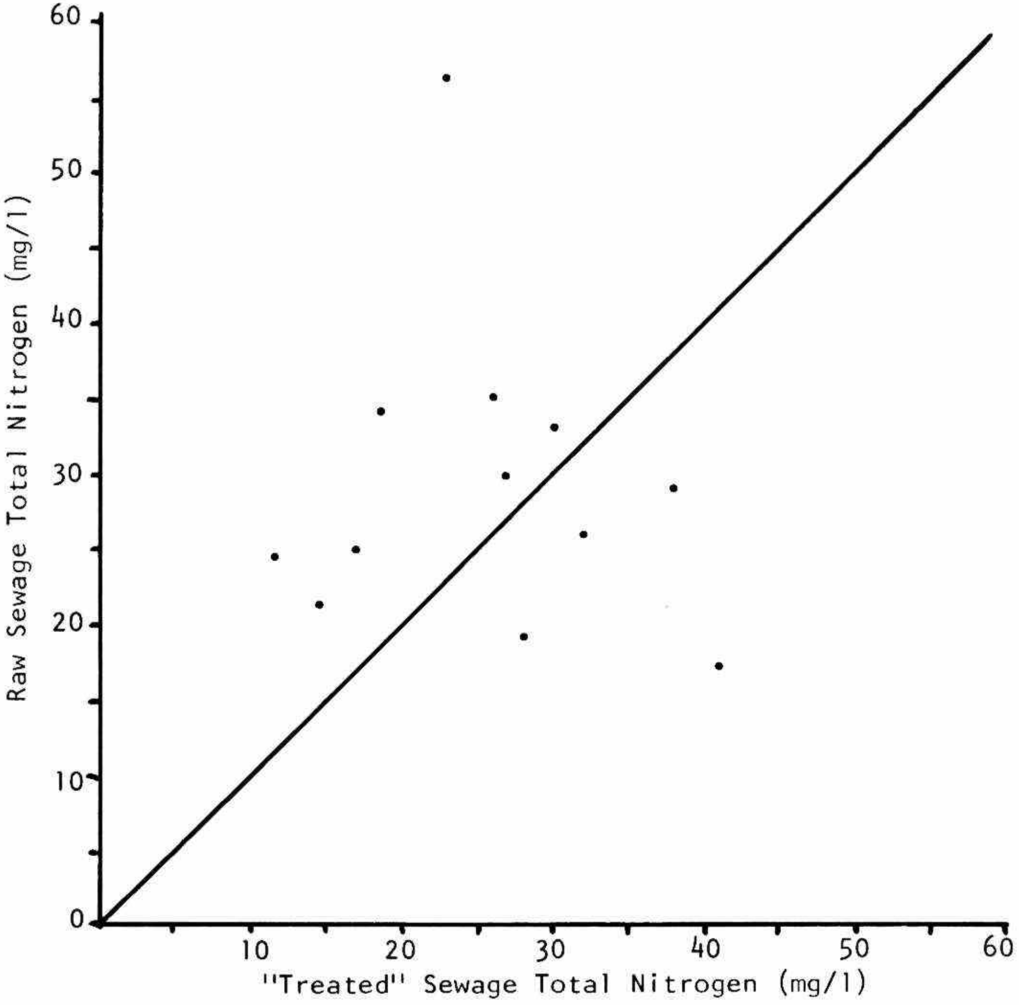

FIGURE A-4. SUTTON - FERRIC CHLORIDE - A COMPARISON OF THE TOTAL NITROGEN IN THE RAW AND "TREATED" SEWAGE

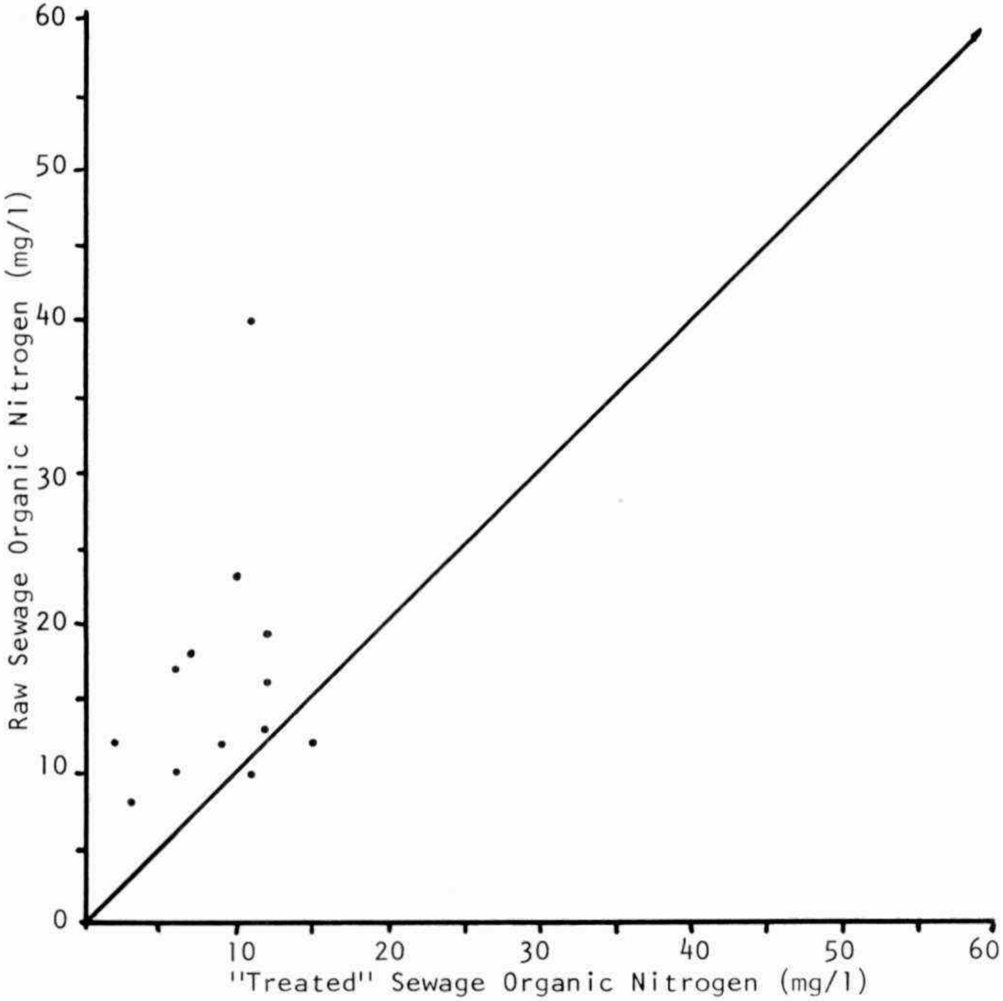

FIGURE A-5. SUTTON - FERRIC CHLORIDE - A COMPARISON OF ORGANIC NITROGEN IN THE RAW AND "TREATED" SEWAGE

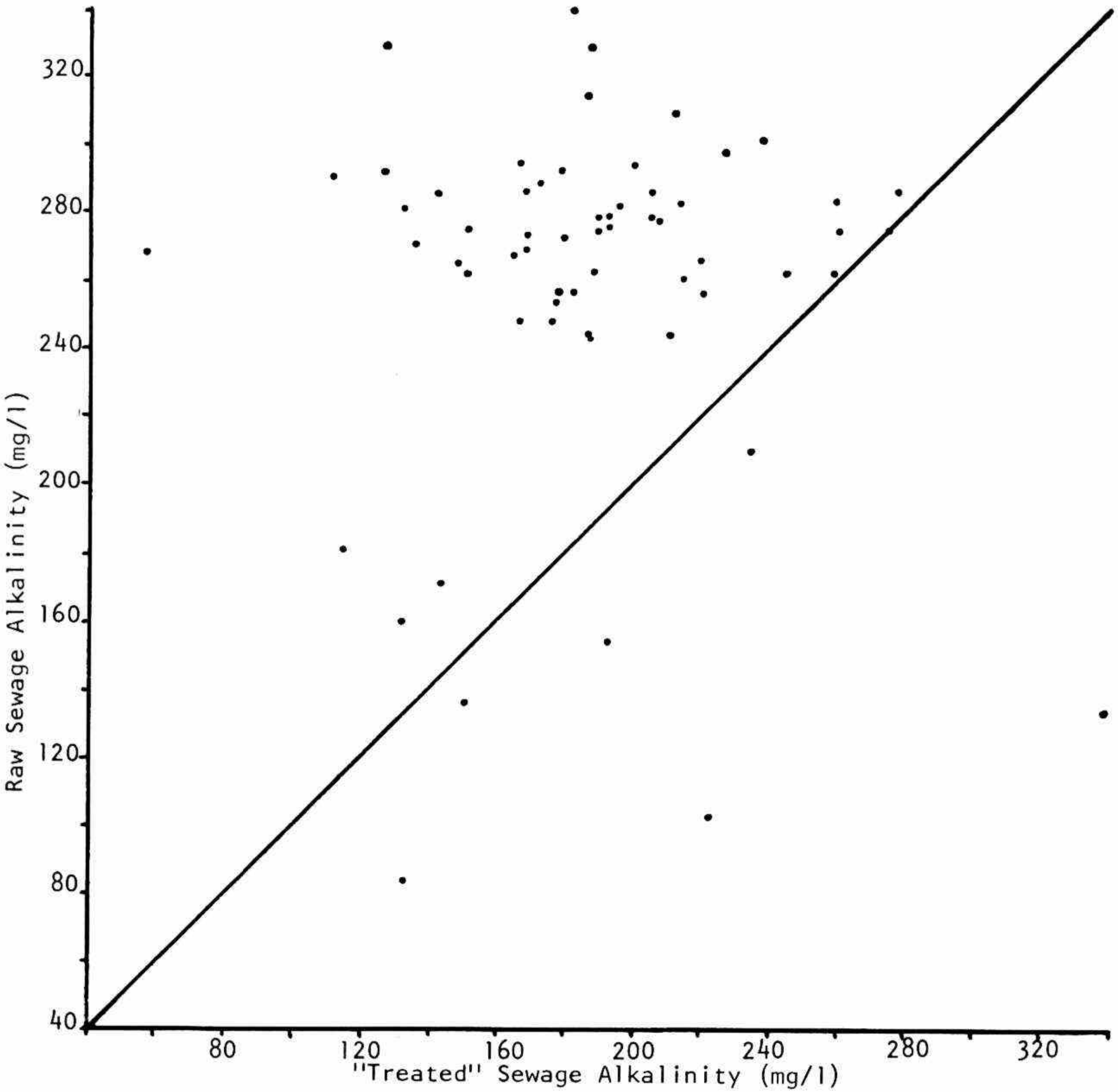

FIGURE A-6. SUTTON - FERRIC CHLORIDE - A COMPARISON OF ALKALINITY IN THE RAW AND "TREATED" SEWAGE

APPENDIX B

SHELBURNE - ALUM

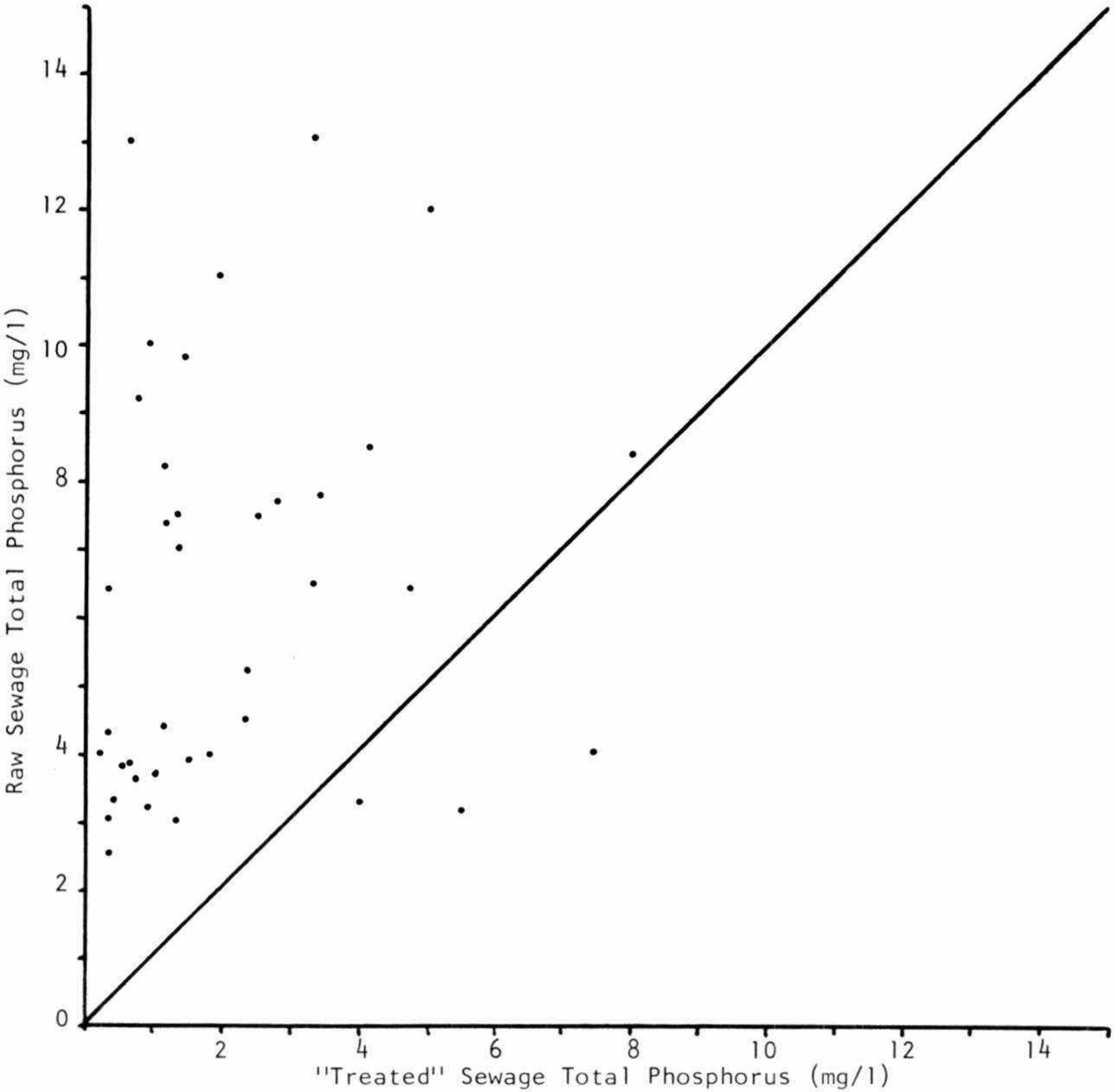

FIGURE B-1. SHELBURNE - ALUM - A COMPARISON OF TOTAL PHOSPHORUS IN THE RAW AND "TREATED" SEWAGE

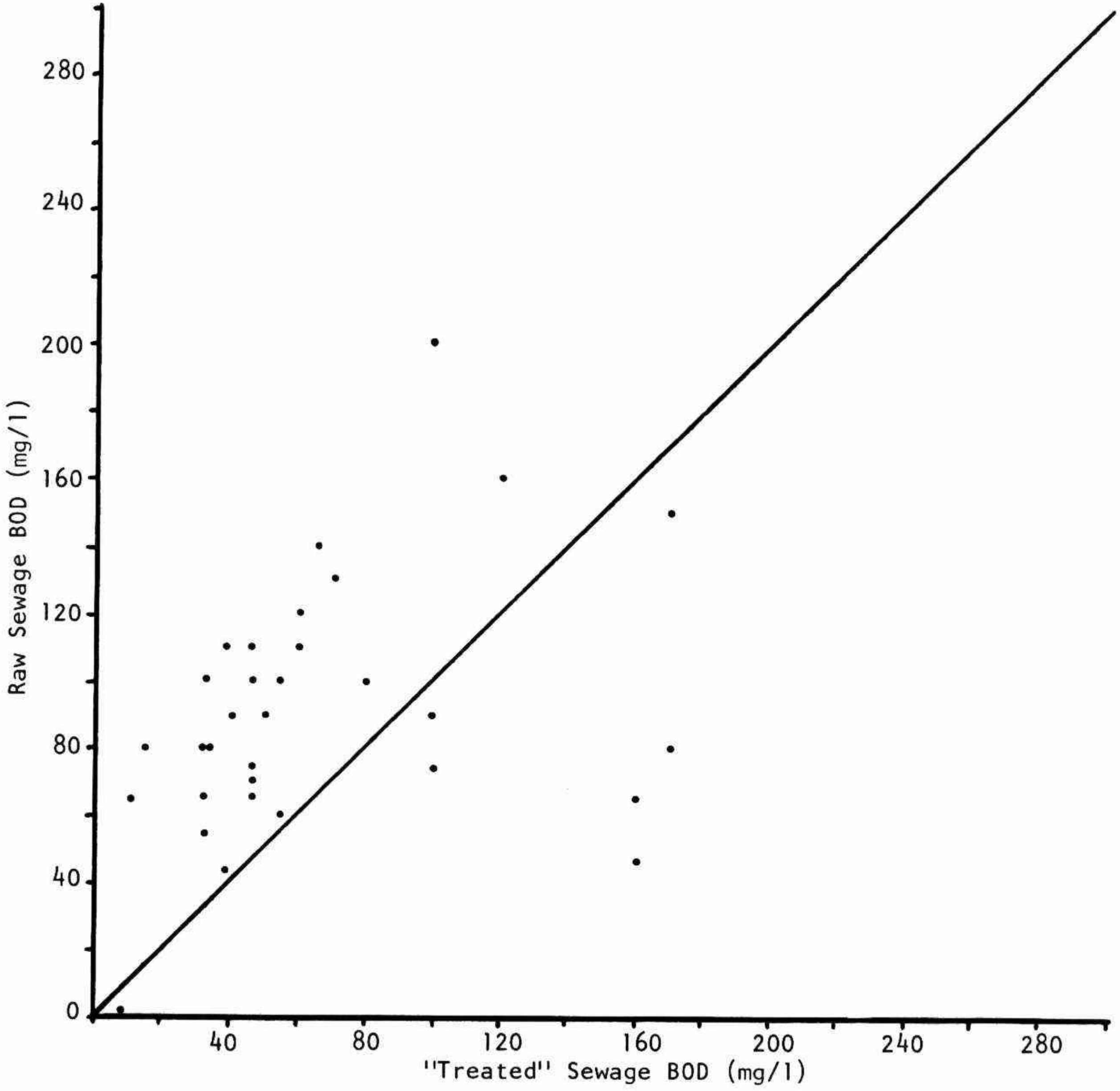

FIGURE B-2. SHELBURNE - ALUM - A COMPARISON OF BOD IN THE RAW AND "TREATED" SEWAGE

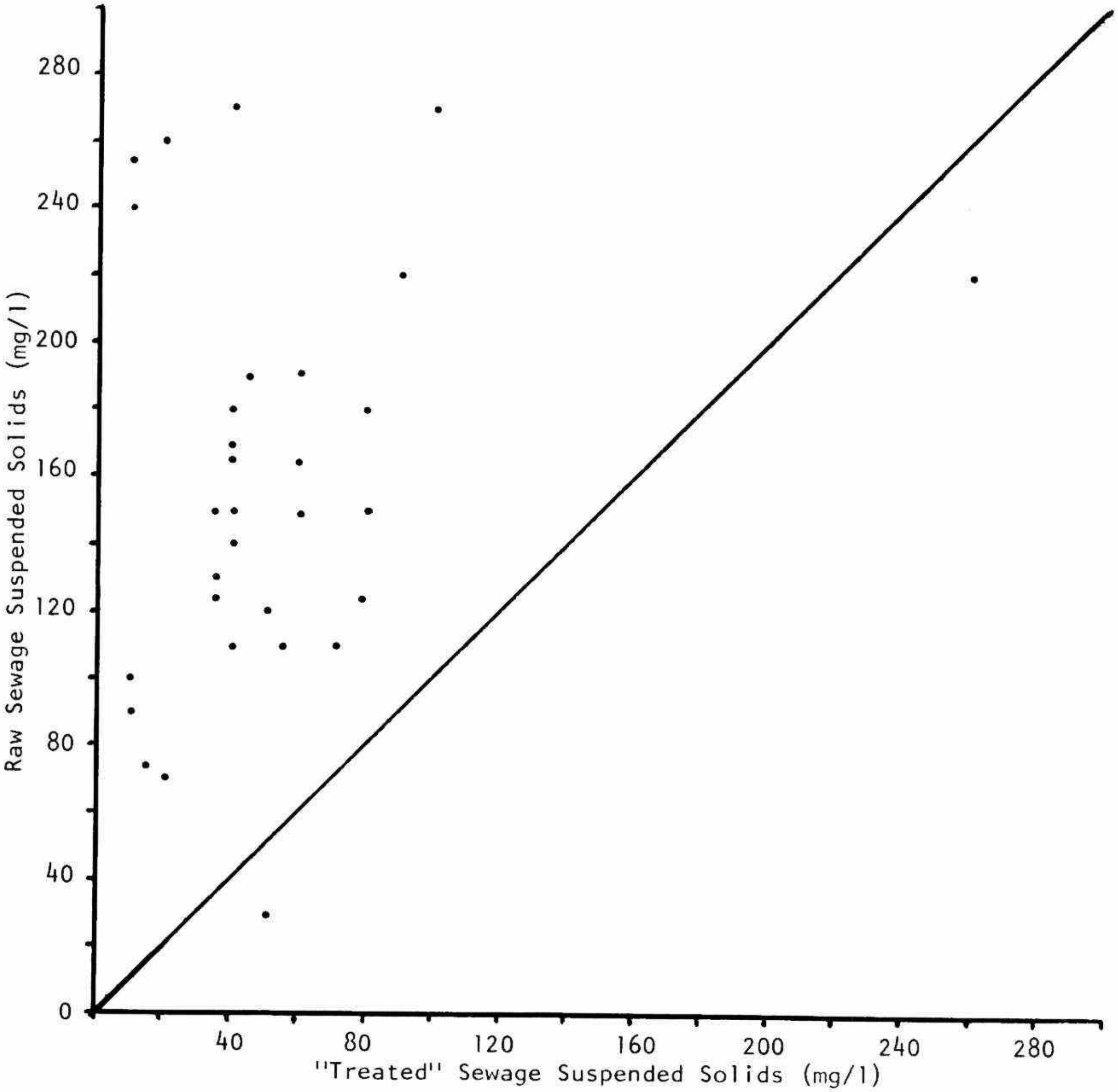

FIGURE B-3. SHELBURNE - ALUM - A COMPARISON OF SUSPENDED SOLIDS IN THE RAW AND "TREATED" SEWAGE

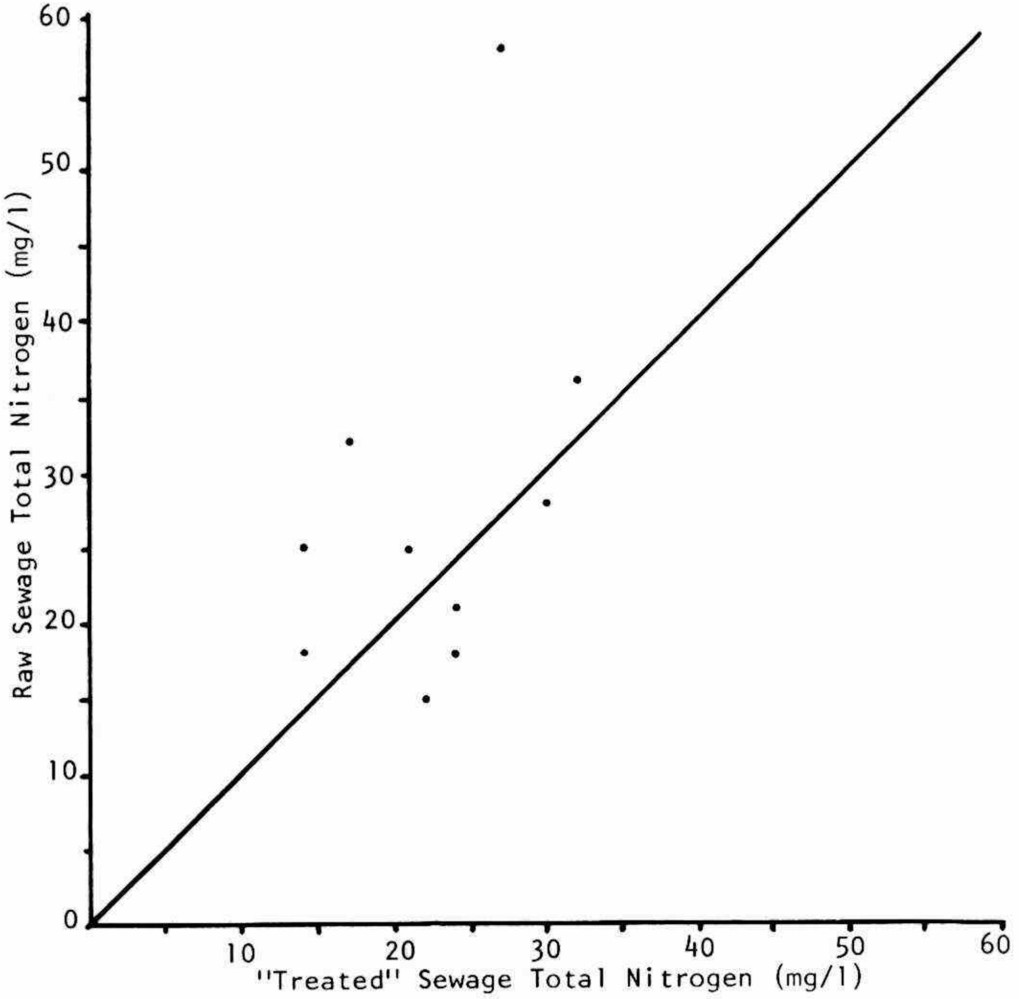

FIGURE B-4. SHELBURNE - ALUM - A COMPARISON OF TOTAL NITROGEN IN THE RAW AND "TREATED" SEWAGE

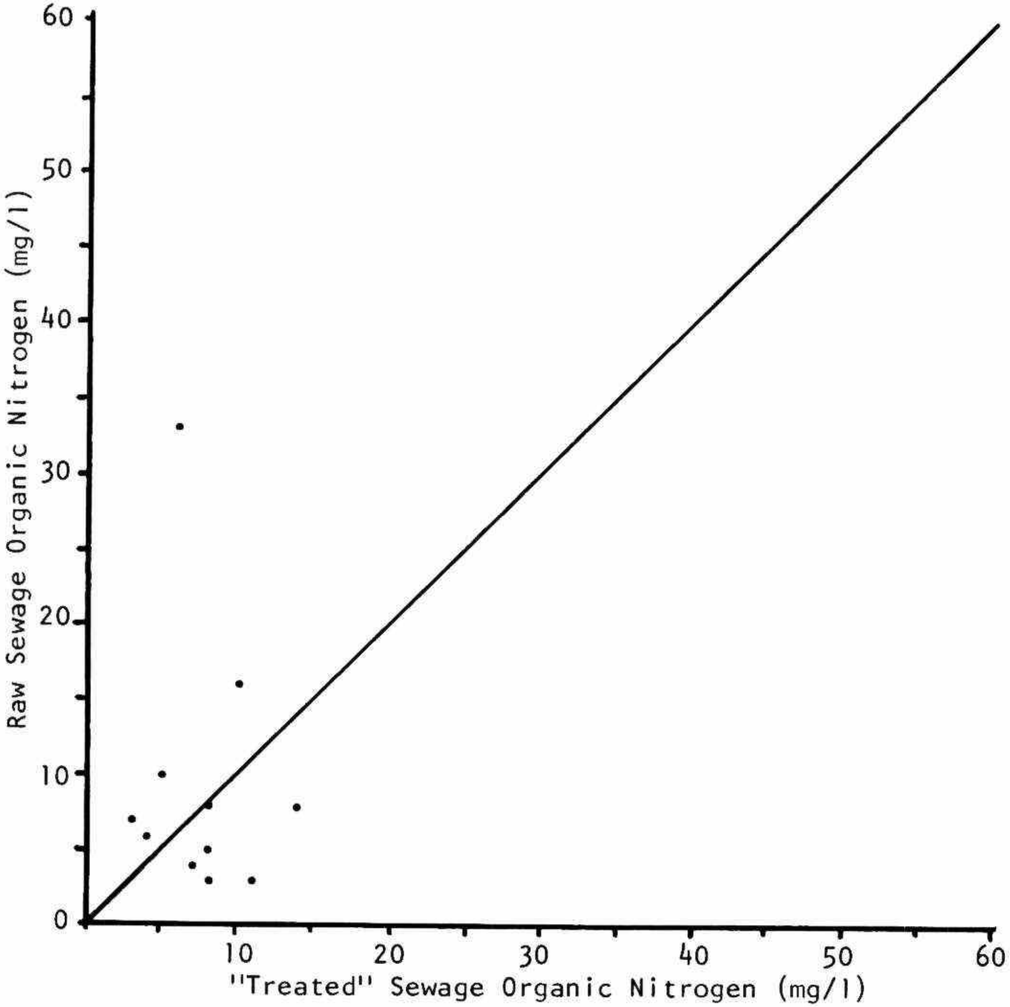

FIGURE B-5. SHELBURNE - ALUM - A COMPARISON OF ORGANIC NITROGEN IN THE RAW AND "TREATED" SEWAGE

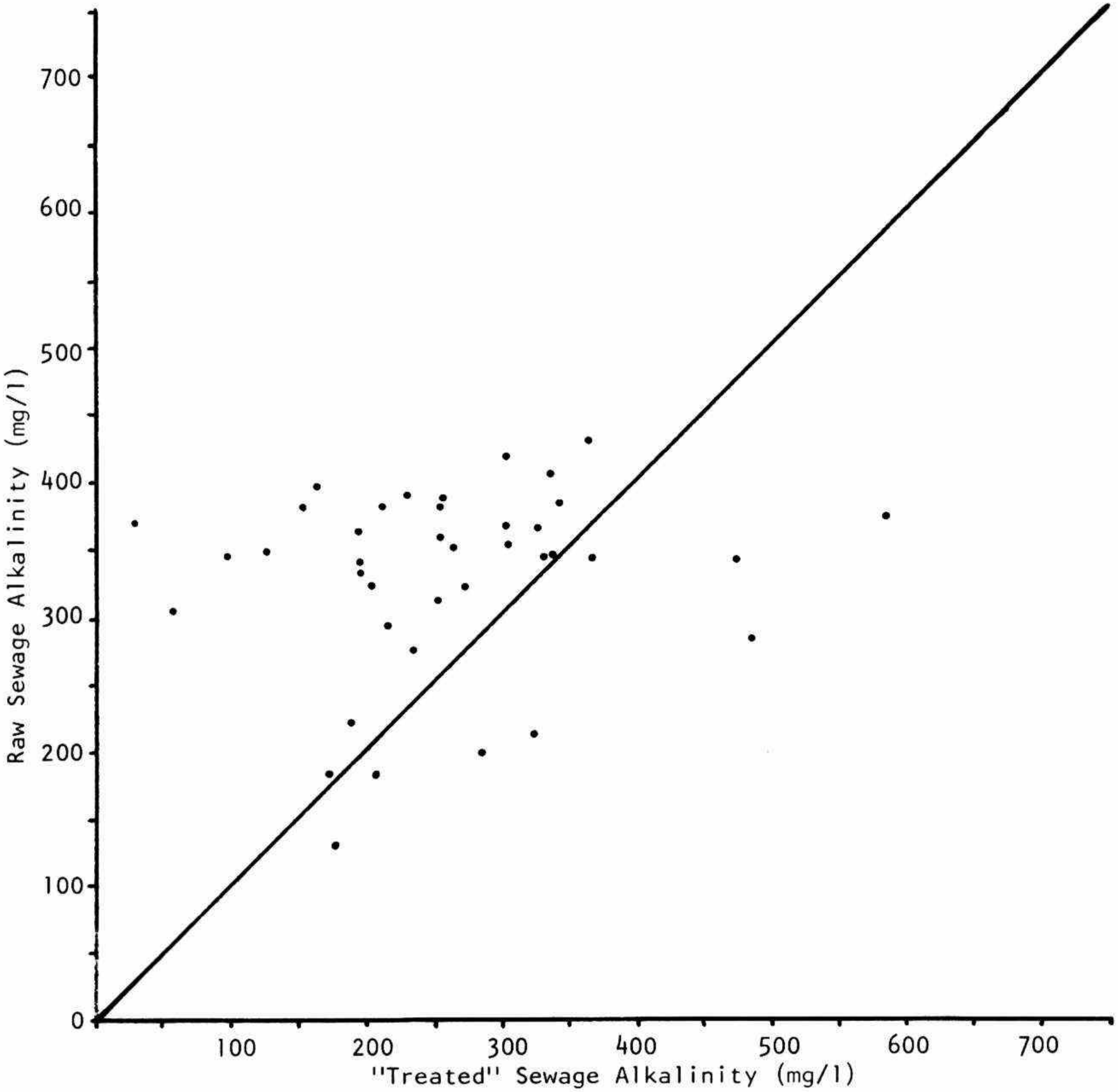

FIGURE B-6. SHELBURNE - ALUM - A COMPARISON OF THE ALKALINITY IN THE RAW AND "TREATED" SEWAGE

APPENDIX C

WATERFORD - LIME

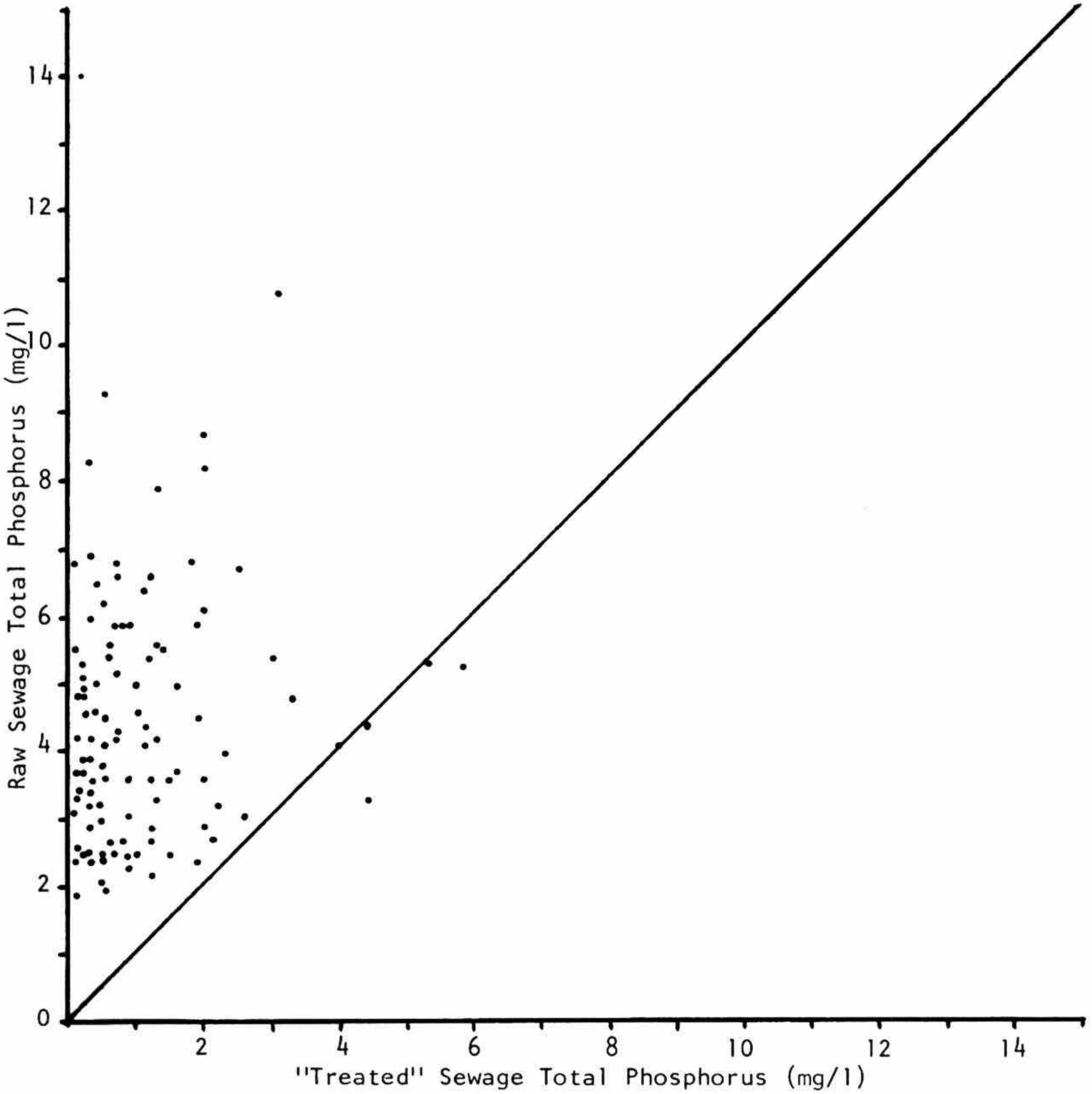

FIGURE C-1. WATERFORD - LIME - A COMPARISON OF TOTAL PHOSPHORUS CONCENTRATIONS IN THE RAW AND "TREATED" SEWAGE

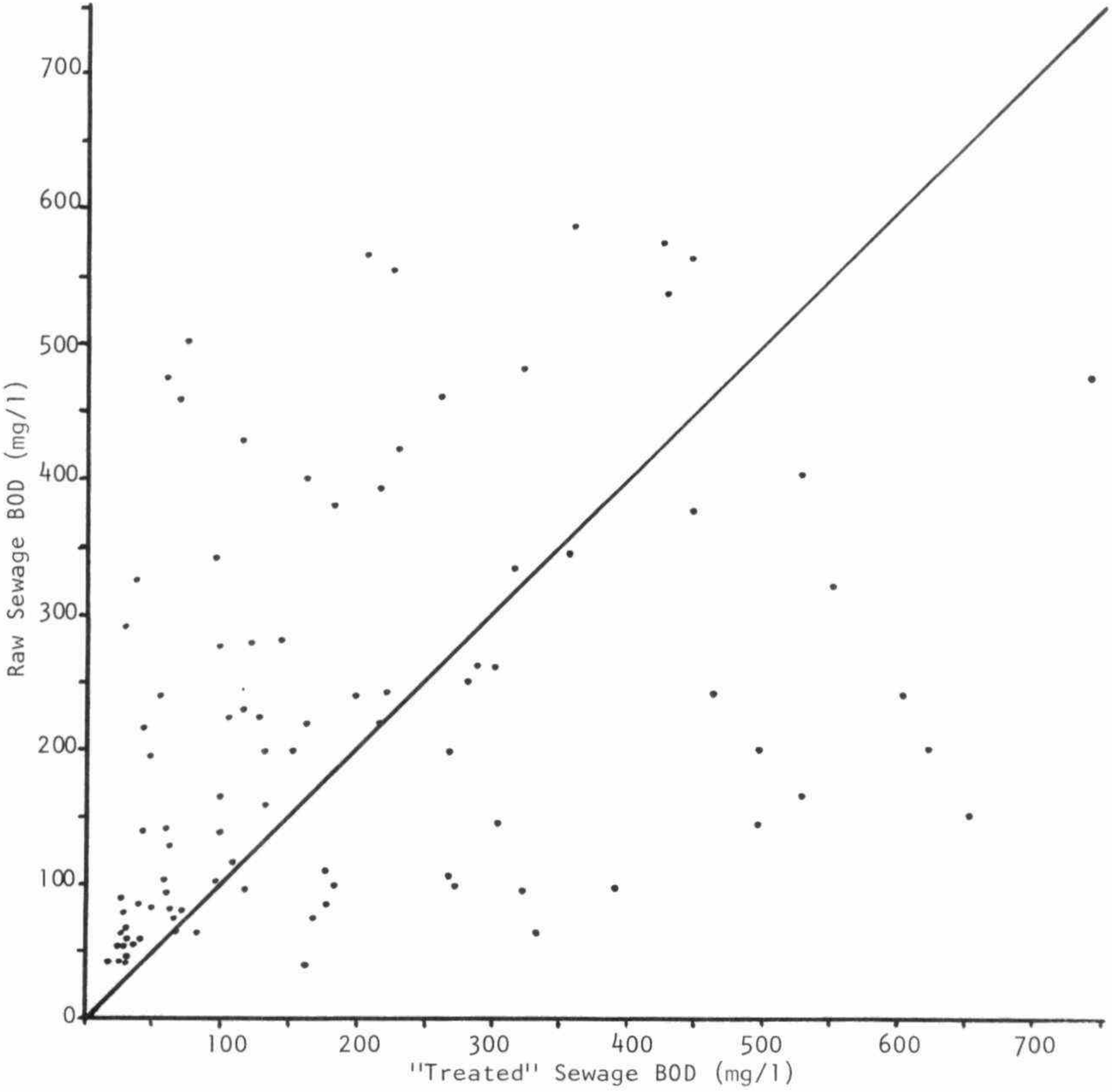

FIGURE C-2. WATERFORD - LIME - A COMPARISON OF BOD LEVELS IN THE RAW AND "TREATED" SEWAGE

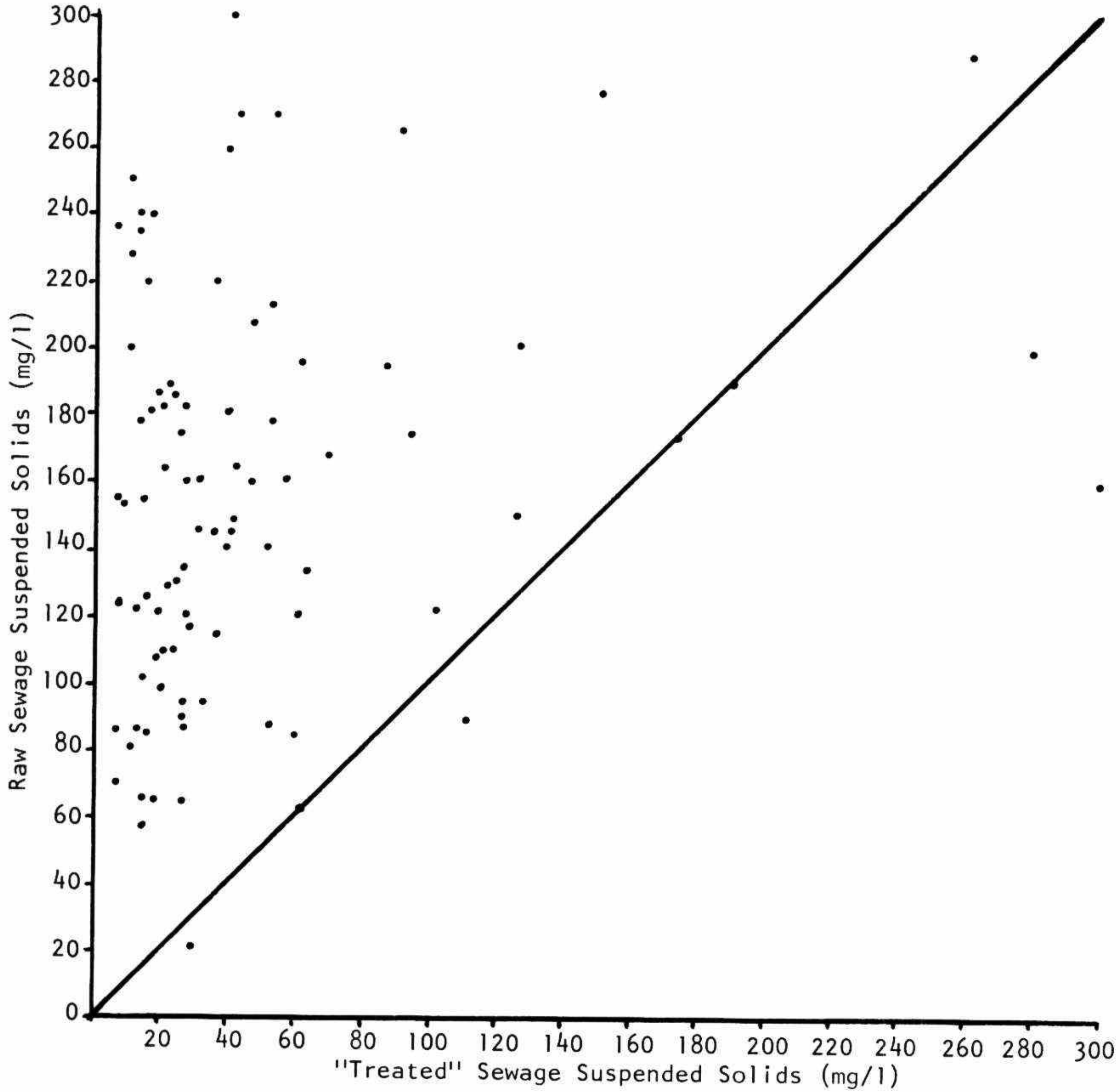

FIGURE C-3. WATERFORD - LIME - A COMPARISON OF SUSPENDED SOLIDS LEVELS IN THE RAW AND "TREATED" SEWAGE

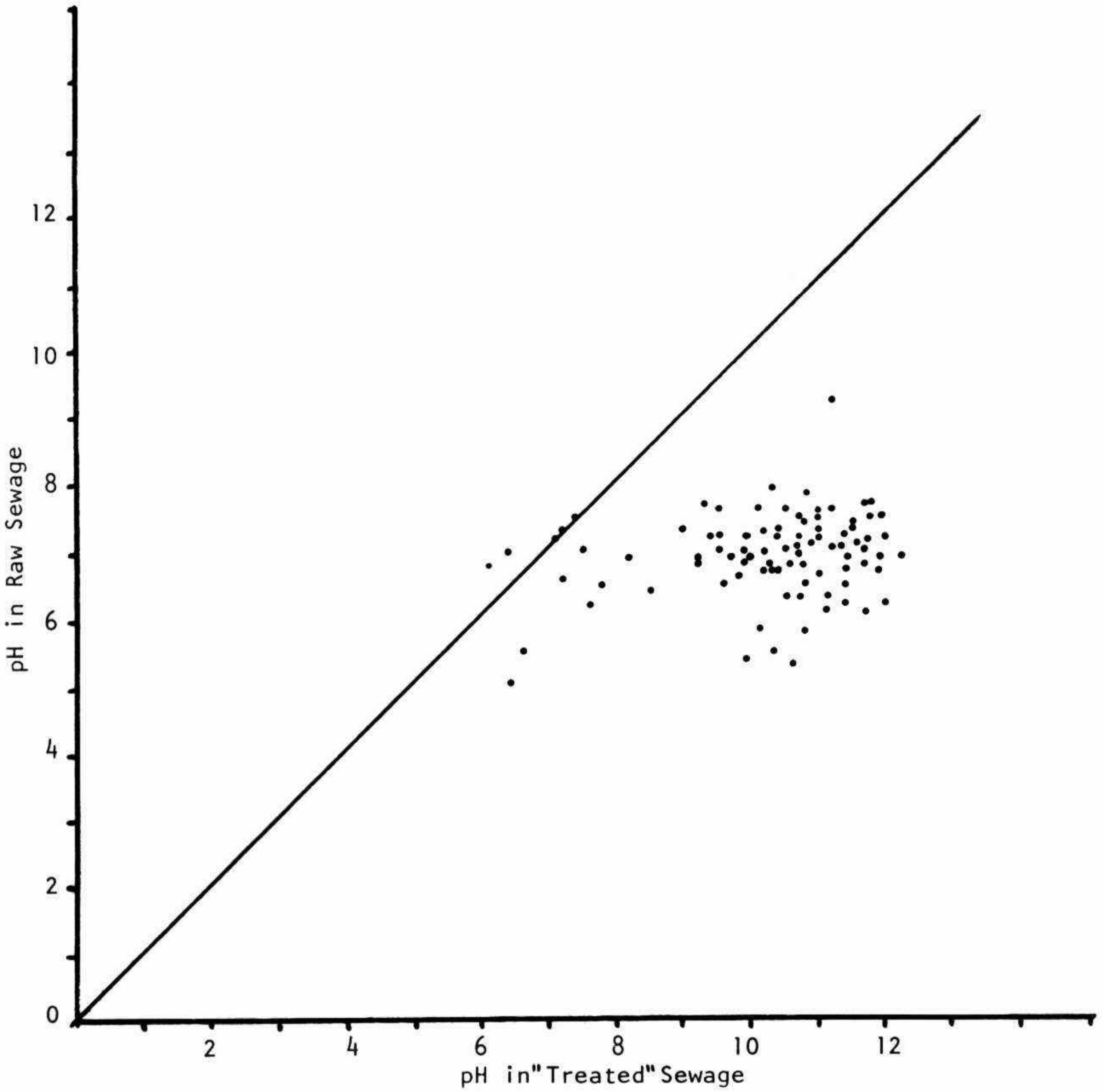

FIGURE C-4. WATERFORD - LIME - A COMPARISON OF pH VALUES IN RAW AND "TREATED" SEWAGE

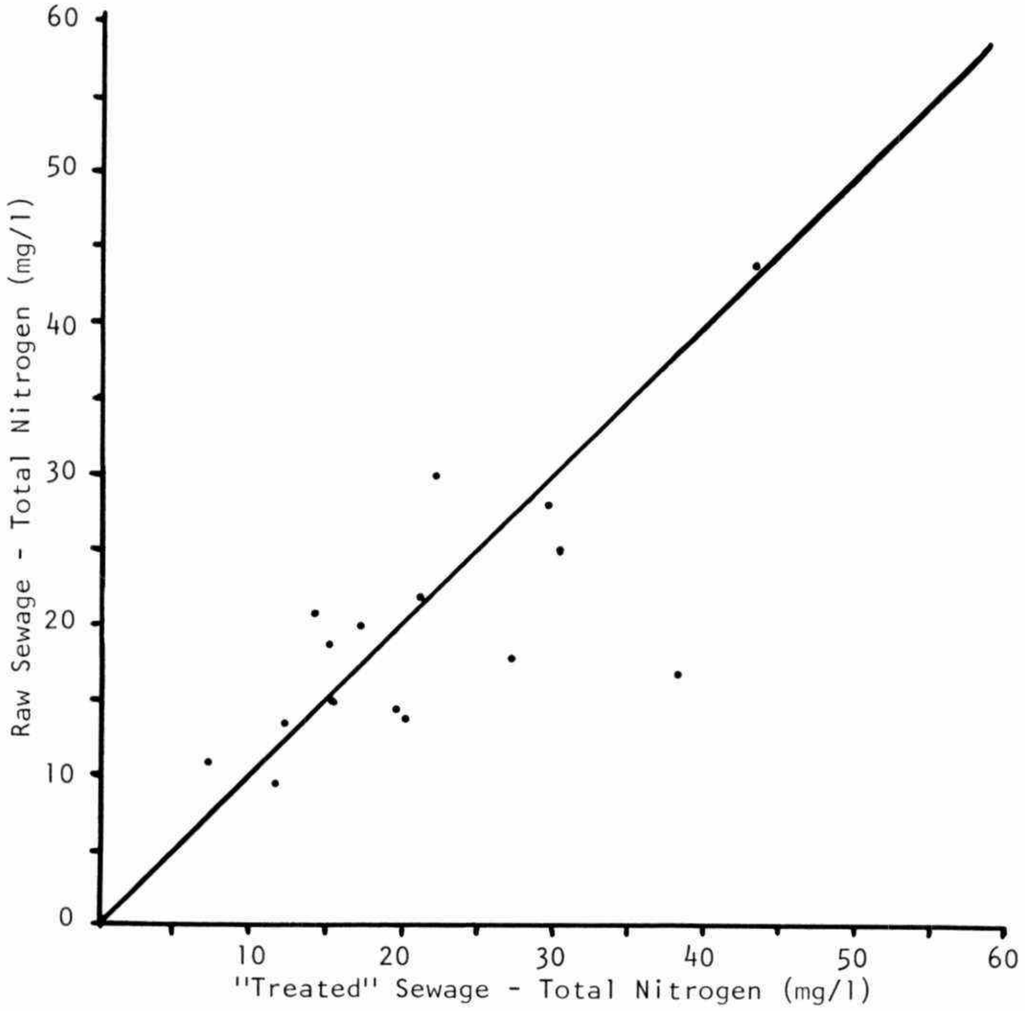

FIGURE C-5. WATERFORD - LIME - A COMPARISON OF TOTAL NITROGEN IN THE RAW AND "TREATED" SEWAGE

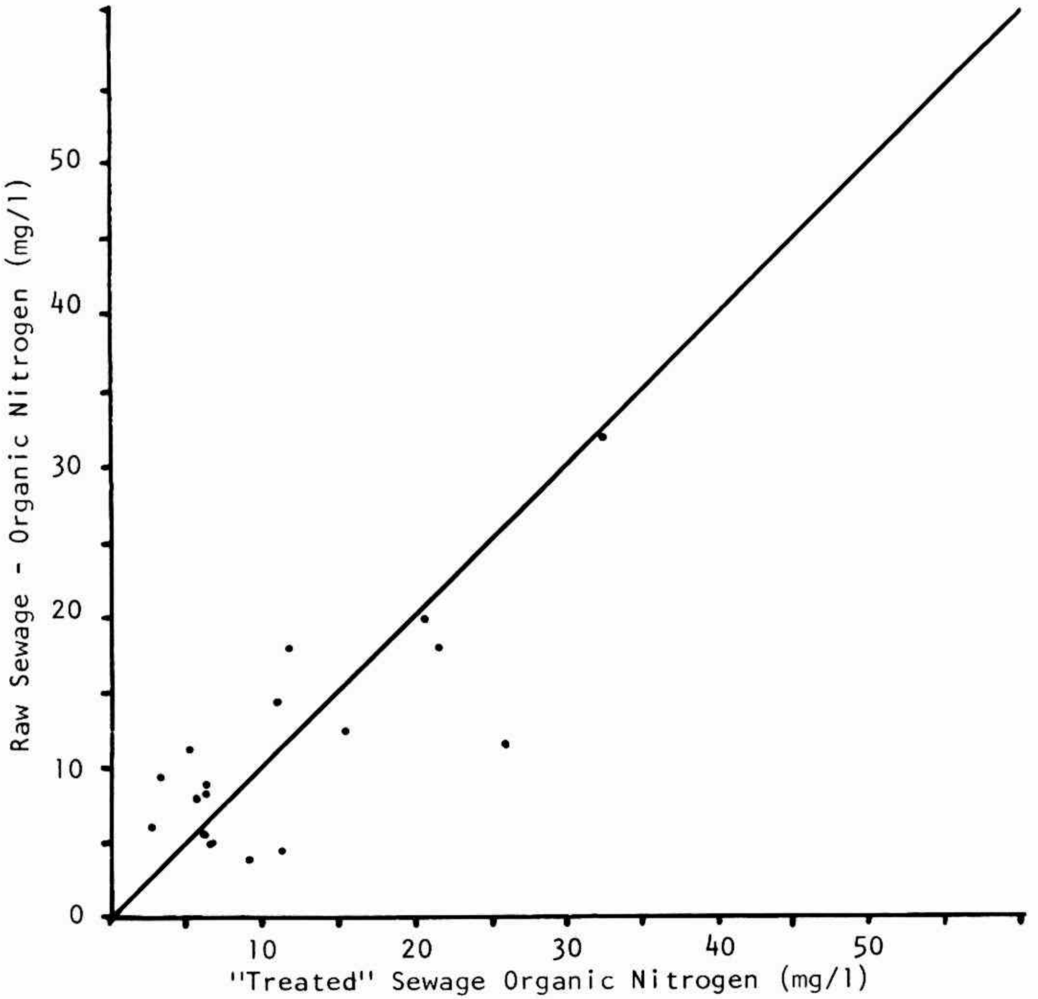

FIGURE C-6. WATERFORD - LIME - A COMPARISON OF ORGANIC NITROGEN IN THE RAW AND "TREATED" SEWAGE

TD
758.5
.P56
G73
1977

Phosphorus reduction from continuous overflow lagoons by addition of coagulants to influent sewage. Graham, H. J.
78904

MINISTRY OF THE ENVIRONMENT
RESOURCE RECOVERY BRANCH

REC: NOV 15 1977

FILE:

TO	INITIAL